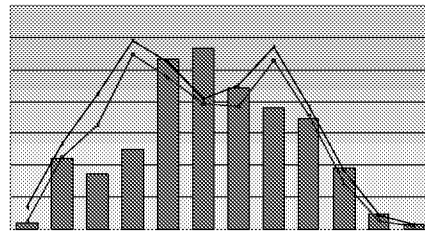
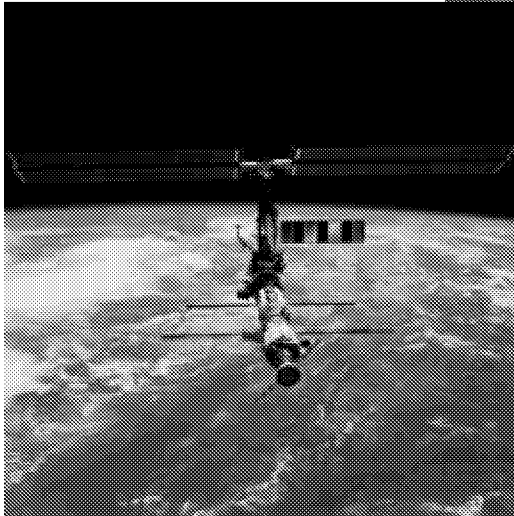
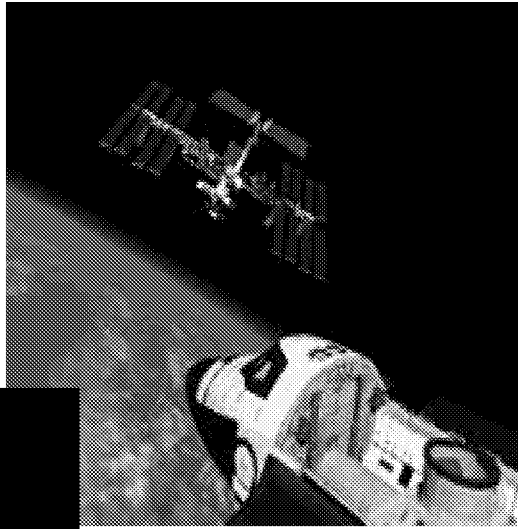
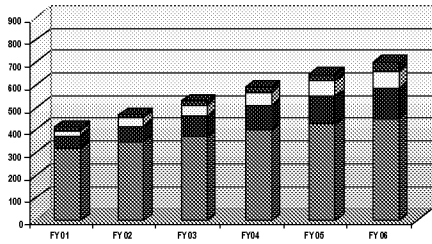


**Report
by the
International Space Station (ISS)
Management and Cost Evaluation (IMCE)
Task Force**



**to the
NASA Advisory Council**

November 1, 2001

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PREFACE

A primary mission of the National Aeronautics and Space Administration (NASA) is

“To advance human exploration, use, and development of space.”

We have developed this report upon this premise. The International Space Station (ISS) objectives require the establishment of a long-term human presence in space. A clear articulation of the mission of ISS within the broader context of the human exploration of space would greatly benefit the setting of research priorities for the station.

Although the configuration of the Space Station has been modified, the fundamental purposes remain scientific research and international cooperation. Specific objectives are:

- To provide the means to sustain humans during extended space flight. This will require a primary research focus on discovering any adverse effects of long-term human presence in space.
- Perform “world class” scientific research that requires low gravity and is enhanced by astronaut interaction.
- Enhance international cooperation and U.S. leadership through international development and operations of ISS.

A critical element required for the overall ISS Program is a commitment to a long-term plan for transporting astronauts to and from the ISS.

We offer this report in response to the Terms of Reference (Appendix A) jointly established by NASA and the Office of Management and Budget (OMB). We believe the recommendations contained in this report will enhance the probability that a credible ISS core complete program can be established. We also believe a responsible plan is offered to move beyond core complete to a fully capable ISS if justified by NASA performance.

The International Space Station Management and Cost Evaluation Task Force (IMCE) commends the many dedicated NASA, international partners, support teams, and contractor personnel who contributed to this report. While these individuals provided constructive comments and suggestions, responsibility for the content of the final report rests entirely with the IMCE. Further, the findings and recommendations in this report are those of the IMCE.

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1.0 Executive Summary

The International Space Station (ISS) Management and Cost Evaluation Task Force (IMCE) was chartered to conduct an independent external review and assessment of the ISS cost, budget, and management. In addition, the Task Force was asked to provide recommendations that could provide maximum benefit to the U.S. taxpayers and the International Partners within the President's budget request.

The Task Force has made the following principal findings:

- ❖ **The ISS Program's technical achievements to date, as represented by on-orbit capability, are extraordinary.**
- ❖ **The existing ISS Program Plan for executing the FY 02-06 budget is not credible.**
- ❖ **The existing deficiencies in management structure, institutional culture, cost estimating, and program control must be acknowledged and corrected for the Program to move forward in a credible fashion.**
- ❖ **Additional budget flexibility, from within the Office of Space Flight (OSF) must be provided for a credible core complete program.**
- ❖ **The research support program is proceeding assuming the budget that was in place before the FY02 budget runout reduction of \$1B.**
- ❖ **There are opportunities to maximize research on the core station program with modest cost impact.**
- ❖ **The U.S. Core Complete configuration (three-person crew) as an end-state will not achieve the unique research potential of the ISS.**
- ❖ **The cost estimates for the U.S.-funded enhancement options (e.g., permanent 7-person crew) are not sufficiently developed to assess credibility.**

The Task Force has the following primary recommendations:

- **Actions required to develop and implement a credible U.S. core complete program within the President's FY02 Budget Blueprint (Appendix B):**
 - **Major changes must be made in how the ISS program is managed**
 - **Additional cost reductions are required within the baseline program**
 - **Additional funds must be identified and applied from the Human Space Flight budget**

- **A clearly defined program with a credible end - state, agreed to by all stakeholders, must be developed and implemented**
- **Actions required to maximize research within the President's FY02 Budget Blueprint:**
 - **Scientific research priorities must be established and an executable program, consistent with those priorities, must be developed and implemented**
 - **Additional crew time must be allocated to support the highest priority research**
 - **Science leadership must be established at the highest level within the ISS Program Office**

2.0 Specific Findings

In performing an independent external review and assessment of cost, budget, and management of the ISS, the IMCE Task Force (Appendix C) has made the following specific findings:

The ISS Program, while taking a conservative approach and making safety paramount, has achieved excellent progress in integration of diverse international technologies.

Assembly of the ISS began in November 1998 with the launch of the Russian Zarya module. To date there have been 21 missions, including assembly and logistics/utilization. All have been successful, with no major anomalies. Having completed the ISS phase that has enabled early research, a three-person permanent crew has been established and the keystone elements of three of the five international partners have been successfully deployed. The assembly, integration, and operation of the complex systems have been conducted with extraordinary success, proving the competency of the design and the technical team. The ISS has been assembled, outfitted with tons of equipment and supplies for the health and safety of future crews, and initial research is underway. Twenty kilowatts of renewable electric power is being produced, more than ever generated in space. The elements that will comprise the 300 foot ISS truss structure are being readied for launch in 2002 and early 2003. The risk in design and development of the vehicle has been largely retired.

NASA has not accomplished a rigorous ISS cost estimate. The program lacks the necessary skills and tools to perform the level of financial management needed for successful completion within budget.

NASA cannot rationalize the cost estimating variances in the FY02 budget formulation process by merely suggesting that it is largely due to the complexity of the program. The underestimation of remaining development and operations costs, along with the continued escalation of cost estimates even into the IMCE review period, is a clear indication of inadequate methodology, tools, and controls. There is no common guideline for the generation of estimates across the program. There are multiple budgeting techniques and multiple reporting techniques. NASA ISS support and ISS contractors estimate and report in a myriad of methods. Financial forecasting and strategic planning suffer from insufficient “forward” analysis and planning due to division of financial authority and responsibility, lack of experienced financial personnel and modern tools, diverse and often incompatible accounting systems, and uneven and non-standard cost reporting capabilities.

The cost to achieve comparable expectations at assembly complete has grown from an estimate of \$17.4B to over \$30B. Much of this cost growth is a consequence of underestimating cost and a schedule erosion of 4+ years.

Much of the cost growth is attributable to clearly delineable areas such as: inadequate initial requirements definition, added content, late element delivery, development problems leading to cost variance, inadequate understanding of international integration

requirements, and increased institutional charges on the program. In addition, imposition of annual budget caps forced the program to an inefficient spend profile and reinforced the management's focus on meeting annual budgets rather than on total cost management.

A cost of \$8.3B (FY02-06) is not credible for the core complete baseline without radical reform.

The Task Force unanimously concluded that the current program plan is not credible. Task Force concerns included management and program control deficiencies as well as overly optimistic cost avoidance initiatives. Additionally, the Task Force thought the remaining development and integration risk, including research facilities, is underestimated and the level of unencumbered program reserves is inadequate.

The NASA/Office of Management and Budget (OMB) agreement for the FY02 budget (FY02-06) was \$8.3B, including a NASA management challenge (shortfall) of \$484M and unencumbered reserves of \$750M. During the review, new cost increases totaling \$366M were identified. Additional, but uncosted, concerns were identified in the area of contractor rates, International Partner cost implications stemming from scaling back the baseline to the U.S. core configuration, the risk of research development activities, and inadequate Preplanned Product Improvement funding. Offsets in the amount of \$440M from within the program were identified. The major portion of these offsets came from projected program staff reductions in operations and sustaining engineering. Approximately \$1B of potential additional savings from within OSF were later identified by NASA. These estimates result from both a shuttle flight rate revision and the on-going Strategic Resources Review (SRR)/institutional savings effort. Part of the projected savings come from reducing civil service staffing across OSF. Successful completion of the core complete program is dependent on increased funding flexibility and savings within the program and other OSF activities, as well as management reform and a credible program roadmap. The latter two issues are discussed elsewhere in this report.

The Task Force expressed concern with respect to the required budget flexibility , including validity of the original \$8.3B cost estimate and the probability of achieving all the projected savings. There was consensus however, that given the other steps recommended in this report, there is a reasonable chance of successfully executing the core program.

The management focus is on technical excellence and crew safety with emphasis on near- term schedules, rather than total program costs.

Human Space Flight programs have historically been focused on protecting crew safety; this is particularly true during the crucial launch phase when issues must be acted upon in an instant. A large percentage of employees working on the ISS program have gained their skills and experiences on the Shuttle and earlier manned programs. There are many indications this experience base and culture have been transferred to the ISS program. As an example, a substantial sustaining engineering function has been established separate from the operations structure.

The Task Force believes this approach is not necessary and it is possible to “dual-use” engineer-operators to reduce overall cost. Since the ISS is a crewed vehicle, many of the anomalies can be stabilized by the crew and addressed with technical expertise on the ground that is “on-call” and not “on-tap.” While this may reduce ISS availability somewhat, it could substantially reduce required manpower. As the Shuttle-Mir Program has proven, a space station has much different attributes that would allow for lower staffing levels. While the currently planned ISS staffing levels will enable continued high levels of response, the Task Force considers them to be unnecessary.

The Program is being managed as an “institution” rather than as a program with specific purpose, focused goals and objectives, and defined milestones.

The institutional needs of the Centers are driving the Program, rather than the Program requirements being served by the Centers. The impact of institutional management is clearly indicated in the overall staffing levels of the program. The institution, not the program, controls the majority of these resources and timely destaffing is significantly hindered. At this phase of the ISS program, deleting more hardware saves very little money since the bulk of the expenditures are in the “people” category.

The financial focus is on fiscal year budget management rather than on total Program cost management.

At the time the Space Station was redesigned in 1994, annual budget caps of \$2.1B were levied on the program as a means to control costs. In general, such caps establishing level annual funding on a major program are counterproductive to controlling total program cost. Total cost and schedule became variables as NASA’s focus became one of executing the program within the annual budgets. Additional funding was requested and provided for the Russian Program Assurance and Crew Return Vehicle (CRV) efforts. To stay within the annual budget caps, basic program content slipped and the total program cost grew. The final ISS cost estimate at completion has not been a management criterion within NASA.

Lack of a defined program baseline has created confusion and inefficiencies.

The President’s FY02 Budget Blueprint and the subsequent NASA/OMB agreement relative to the “U.S. Core” program allow for NASA to maintain critical skills necessary to build additional content. At the start of the IMCE review, it appeared the ISS Program was still assuming the “Program Manager’s” Recommended Program (\$8.3B + \$2.5B) was the baseline and that the core complete program was an option. The research support element of the ISS is still being implemented according to the original program and has been unable to take action in FY01 to terminate certain research activities. The scientific community is confused and considers the reduction to a three-person crew, from the seven-person crew baseline, to have a significant adverse impact on science. The International Partners believe the U.S. cannot unilaterally change the previously existing baseline assembly sequence.

Current research support funding represents a 40-percent reduction in buying power from that originally planned.

When the Space Station Program was redesigned in 1993, the research support budget of \$3.8B through assembly complete was programmed for research facilities and for recurring utilization. Between 1993 and 2001, the ISS Program experienced major delays, which resulted in slippage of the program schedule. As deviations in the program schedule occurred, the research support budget was realigned to keep synchronicity with the program. Consequently, the funding was taken out of the near-term years and was reinstated in the out years. During this process, the design, development, and fabrication of the research facilities were being delayed and experienced a cost inefficiency. This inefficiency in combination with 4.5 years of inflation and \$0.4B funding for Mir has reduced the buying power of research funds by 40 percent. The total budget of \$3.8B has not changed appreciably, but has been spread over a 13-year period for less capability. Discounting for the above factors (40 percent), the buying power of the current budget (\$1.6B budget through FY02 – FY06) is approximately \$2.3B.

The Office of Biological and Physical Research (OBPR) is not well coordinated with the Office of Space Flight (OSF) or the program office for policy and strategic planning. The scientific community representation is not at an effective level in the program office structure.

The transfer of research support budget responsibility to OBPR underscores the need for increased and continuing coordination with OSF. Some progress had been made through the inclusion of OBPR in the OSF management council. The recommendation for a realignment of the program office reporting chain, addressed later in the report, would alleviate this issue. Additionally, the recommendation to establish a Deputy for Science in the program office reverts to an earlier structure and will provide appropriate visibility for the science community.

A centrifuge is mandatory to accomplish meaningful biological research. Availability as late as FY08 is unacceptable.

The centrifuge facility is essential for performing the most promising ISS “world class” biological research. It is critical for fundamental space biology and for the foundation of biomedical research because it provides the control needed for the interpretation of experimental results. This Task Force (and other science groups) has said that this type of research cannot be done without a centrifuge and adequate crew time. The centrifuge is now being constructed by the National Space Development Agency of Japan (NASDA) as part of a barter agreement. Because of budget and technical issues the centrifuge delivery has been delayed until Calendar Year (CY) 08.

There are opportunities to maximize scientific research on the core station with modest cost impact.

The crew time available with a permanent crew of three persons can be effectively doubled by extending sortie mission crew time aboard the ISS. This can be accomplished

by overlapping planned Soyuz exchange periods so that the visiting crew is aboard ISS for a period of 30 days every 5 months. Using existing Extended Duration Orbiter (EDO) capability could allow for Shuttle docked time of up to 14 days. The increased research benefit derives primarily from offloading ISS maintenance tasks to the visiting Shuttle crew. However, there will be significant microgravity constraints due to the Shuttle being docked to the station, as well as crew transfer and maintenance operations.

Cost estimates for the U.S.-funded enhancement options need further development to assess credibility.

The proposed enhancement options consist of various combinations of habitation, life support, and crew return capability. There is inadequate current costing information associated with the non-U.S. components (Enterprise, ASI Hab, and additional Soyuz). The CRV cost estimate of \$1.3B is plausible, with several development and acquisition assumptions that have yet to be verified. Project interruptions will have cost impact on all of the elements under consideration.

3.0 Specific Recommendations

Establish the ISS Program Office separate from, but residing at JSC, reporting to a new Associate Administrator (AA) for the ISS.

The new Associate Administrator's office would combine the ISS-related functions of OSF and OBPR and have program oversight responsibility. It is imperative this new office ensures continuity of program checks and balances in quality and technical oversight. ISS offices at other supporting Centers would report to the ISS Program Manager, who would own all ISS personnel.

Consolidate prime and non-prime contracts into a minimum number of resulting contracts all reporting to the program office.

Currently, there are over 30 contracts supporting the ISS Program. Consolidate these contracts to achieve a minimum number of resulting contracts, with clearly defined cost performance reporting requirements.

Develop a life cycle technical baseline and manage the ISS Program to total cost and schedule as well as fiscal year budgets.

A life cycle technical baseline must be developed that can be used as the basis for a formal cost estimate. Use the Department of Defense cost assessment approach as a model and develop a full ISS cost estimate. Develop an Integrated Program Management Plan delineating the work to be accomplished; the work breakdown structure; the roles and responsibilities of performing organizations; required resources; schedules; and the management techniques, tools, and reports to be used in implementing the Program. Establish a state-of-the-art management information system. Establish a state-of-the-art planning and control system, including independent cost estimating capability. Finally, the financial and project control function needs to be strengthened significantly in the ISS Program office and NASA Headquarters (AA level).

Consider revising the ISS crew rotation period to 6 months and reducing the Space Shuttle flight rate accordingly. The result would be a delay in U.S. Core complete assembly sequence by up to 2 months. Target cost savings: \$668M,

and

Continue to examine Strategic Resources Review (SRR) and Institutional cost reductions. Target cost savings: \$350M-\$450 M.

These recommendations represent one approach to provide a portion of the required budget flexibility. NASA should continue to refine these estimates and examine other options.

The first two actions would incorporate a 6-month crew rotation cycle starting in FY03. This would result in U.S. core complete moving 2 months to April 2004, and reduce

Space Shuttle annual flight rate required to support ISS to four a year. The resulting cost savings (FY02-06) from this change in assembly sequence and Space Shuttle flight rate reduction would provide an estimated \$188M in ISS savings and \$480M in Shuttle savings.

NASA must also move forward to implement cost savings identified in the Fall 2001 Strategic Resources Review and other institutional savings. This includes items such as facility and lab closures, and civil service staffing reductions needed to realize the \$350M-\$450M cost savings target.

Develop a credible program road map starting with core complete and leading to an end state that achieves expanded research potential. Include gate decisions based on demonstrated ability to execute the program

and

Identify funding to maintain critical activities for potential enhancement options.

The existing U.S. core complete program should not be established as an “end-state” condition. It presents significant research and International Partner implications that could be avoided by implementing a performance-gate approach that would allow increasing research capability based on realized performance to plan. Metrics for evaluating performance should be developed in conjunction with the Administration (OMB). The opportunity to realize the high research potential that many dedicated employees have worked years to achieve will maintain motivation in achieving the cost savings necessary to accomplish the core.

The initial performance gate would be to implement changes required to establish credible/executable (\$8.3B + additions from Human Space Flight) Program by June of 2002. During this period, the IMCE recommends providing (within existing budgets) the minimum funding necessary to keep enhancements viable to return to the fully capable program with minimum cost impact.

The end state should be defined in terms of the science priorities recommended below.

Establish research priorities. The Task Force is unanimous in that the highest research priority should be solving problems associated with long-duration human space flight, including the engineering required for human support mechanisms,

and

Provide the Centrifuge Accommodation Module (CAM) and centrifuge as mandatory to accomplish top priority biological research. Availability as late as FY08 is unacceptable,

and

Establish a research plan consistent with the priorities, including a prudent level of reserves, and compliant with the approved budget.

These are fundamental steps toward maximizing the research benefits of the ISS. The phased implementation of capability envisioned in the “end state” plan must incorporate science priorities, research facilities, and utilization as primary considerations. The Task Force also noted the significance of research in physical and microgravity sciences, and urged they be strongly considered when establishing priorities.

Provide additional crew time for scientific research through the use of extended duration shuttle and overlap of Soyuz missions.

The high-priority fundamental biological research necessary to demonstrate feasibility of future human exploration requires significant ISS crew interaction. Extended Soyuz sortie missions can be implemented in the near future and coupled with Shuttle EDO missions can measurably increase crew time to conduct this research.

Create a Deputy Program Manager for Science position in ISS Program Office. Assign a science community representative with dual responsibility to the Program and OBPR.

The Task Force noted that ISS research objective considerations are not generally given full representation in programmatic decision forums. The creation of a Deputy Program Manager for Science will provide increased and coordinated representation of the scientific communities interest at a high programmatic level.

4.0 IMCE Organization and Process

In July 2001, the NASA Administrator established the IMCE Task Force consisting of experts in the fields of science, engineering, finance, and business to assess the budget, management, and research utilization challenges on the ISS Program and to provide advice to NASA and the administration in this regard. The team was chaired by Mr. A. Thomas Young, with Rear Admiral Tom Betterton serving as deputy chairman. The Task Force's primary objectives were to assess cost estimates for the core U.S. program and potential U.S.-funded enhancements. The Task Force was also asked to identify opportunities for maximizing capability to meet priority research program needs within the planned ISS budget and International Partner contributions.

Because of the international nature of the ISS partnership, the Task Force also extended an invitation to NASA's international partners, (the Canadian Space Agency (CSA), the European Space Agency (ESA), Russian Space Agency (RSA), and the National Space Development Agency of Japan (NASDA)) to have representation as observers.

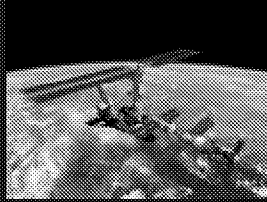
The official kick-off meeting of the IMCE Task Force was held at the NASA Headquarters, Washington DC on August 21-22, 2001 and since then, the members of the Task Force have met on a regular basis. The IMCE Task Force was granted access to all aspects of the ISS program. The Task Force also conducted fact finding trips to meet with the ISS Program management, the organizational support personnel, and the prime contractor. The fact finding concentrated on the trends of past, current, and projections of estimated performance of the ISS Program.

The IMCE Task Force was provided independent assessment support from two teams. The Cost Analysis Support Team (CAST) was directed at cost analysis; the Financial Management Team (FMT) concentrated on performance management systems in the ISS Program. While supporting the IMCE Task Force, these subteams conducted their own independent assessments and provided reports to the Task Force for consideration. The CAST provided a final report (Appendix D). Their findings and recommendations have been incorporated into the body of the IMCE report. The FMT provided only preliminary assessments (Appendix E). Its final findings will be submitted directly to NASA for consideration at a later date.

The Task Force collected information through briefings (program status and special topics), interviews, conversations, other governmental review committees, and from reviewing applicable documentation. These inputs were interpreted and the findings and recommendations formed were then reviewed by the entire Task Force. The main observations and recommendations are presented in the balance of this summary.

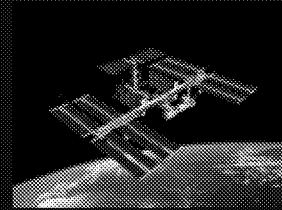
5.0 IMCE Task Force Report

IMCE Task Force Report



International Space Station Management and Cost Evaluation Task Force Report

November 1, 2001



Outline

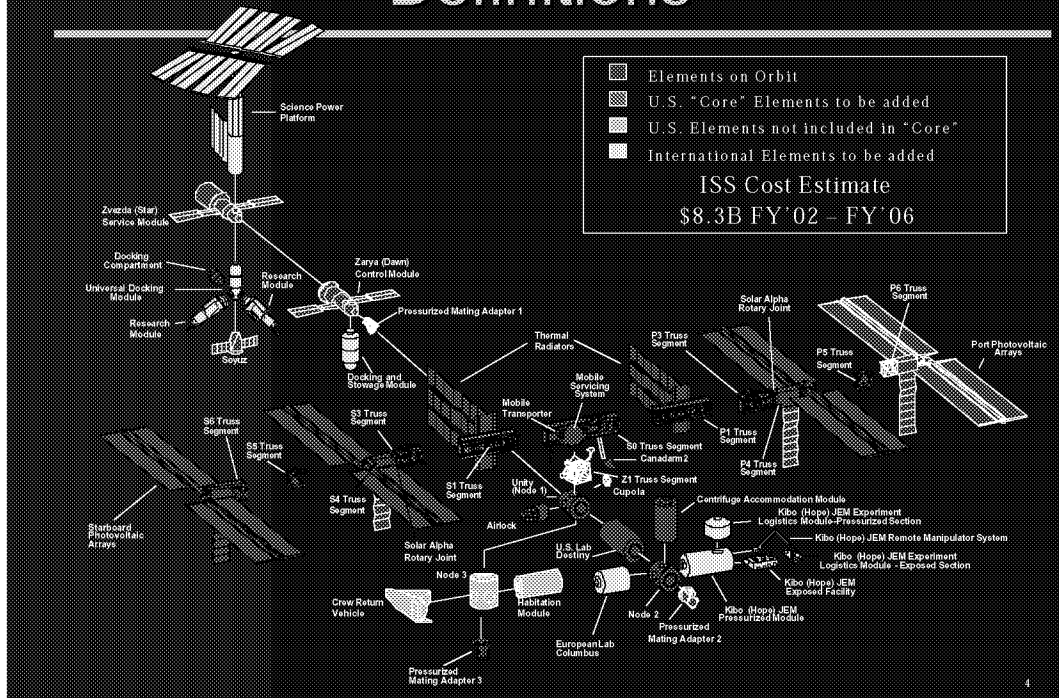
- Charter
- Definitions
- Membership
- Methodology
- Schedule of Activities
- General Observations
- Cost Credibility
- Requirements to Achieve Credibility
- Maximize Research
- Enhancements
- Summary

Charter

- Assess the credibility of the International Space Station (ISS) cost estimate for the approved ISS program, including risks and mitigation strategies.
- Assess program assumptions and requirements and identify options for smaller growth and/or budget savings and efficiencies.
- Identify opportunities for maximizing research within the planned ISS budget.
- Assess cost estimates for potential U.S.-funded enhancements to the core station and recommend refinements as necessary to achieve high confidence estimates.
- Review ISS Program and financial management, tools, and identified reforms, and make recommendations for improvements.
- Provide report to NASA Advisory Council by November 1, 2001.

3

Definitions



4

Membership

Thomas Young, Chair

RADM. Thomas Betterton, Vice Chair

Andreas Acrivos

Kent Black

Peter Bracken

Gregory Canavan

Michael DeBakey

Anthony DeMarco

Susan Eisenhower

William Friend

Robert Grady

Sidney Gutierrez

Bradford Parkinson

ADM. Paul Reason

Robert Richardson

Richard Roberts

Rae Silver

Roger Tetrault

Peter Wilhelm

Brig. Gen. Simon Worden

5

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John Tomick

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Joe Jockel

Staff Support:

Daniel Hedin, Executive Secretary

Steven Schmidt, Executive Assistant

Nantel Suzuki, Executive Assistant

Yvonne Kellogg, Technical Editor

6

Methodology

- Structured Reviews
- Independent Reports
 - Cost Analysis Support Team
 - Financial Management Team
- Executive Sessions
- Scientific Research Session
- Team Discussions

7

Schedule of Activities

<u>Date</u>	<u>Location</u>	<u>Activity</u>
Aug. 20, 21	NASA Headquarters	Kickoff, review plan, fact finding
Sept. 11, 12	Johnson Space Center	Fact finding (Subgroup of total Task Force)
Sept. 25, 26, 27	Johnson Space Center	Fact finding, interviews
Oct. 9,10	NASA Headquarters	Fact finding, interviews, scientific research review, International Partner presentations
Oct. 22, 23, 24	NASA Headquarters	Fact finding, interviews, findings and recommendations
Oct. 30, 31	NASA Headquarters	Report preparation
Nov. 1	NASA Headquarters	Draft Report to NASA Administrator
Nov. 1		IMCE Report Delivered to the NASA Advisory Council (NAC)
Nov. 6	NASA Headquarters	NAC meeting to review IMCE Report

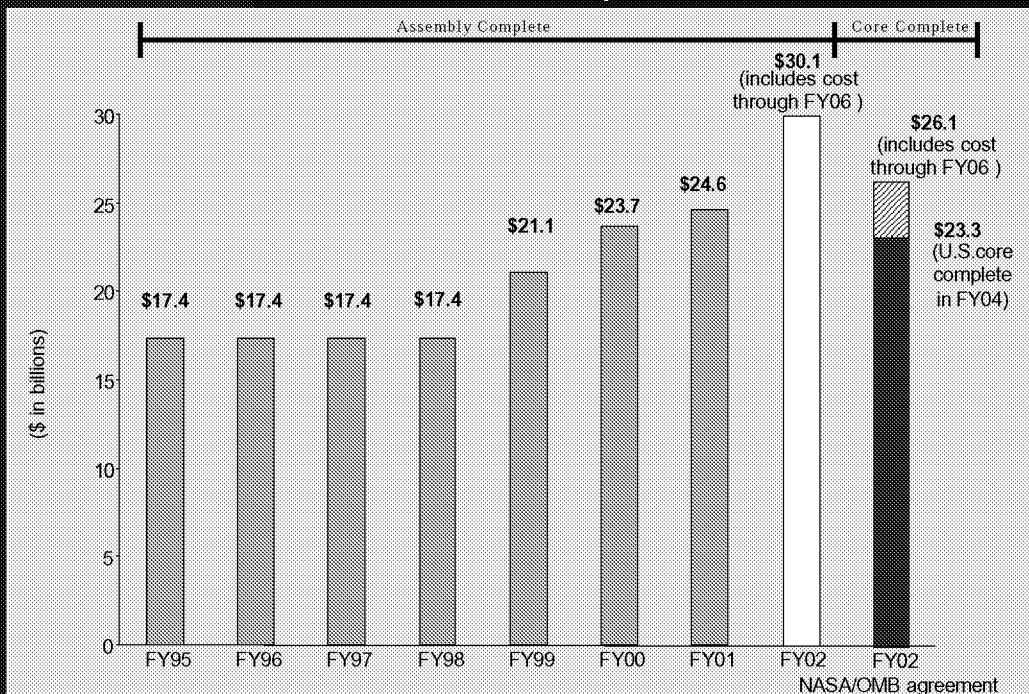
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General Observations

- Outstanding technical accomplishments
 - Operational system in orbit
 - Fully functioning 3-person crew
 - Integration of diverse international technologies
 - Progress, Shuttle, and Soyuz support as required
 - Additional elements progressing toward launch
- Significant schedule delay
 - FY94 Program
 - Assembly complete 6/02
 - FY02 Program (before revisions)
 - Assembly complete 11/06
- Significant cost increase
- Significant reduction in expected science return

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Cost History



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Cost Credibility

Charter

Assess the credibility of the ISS cost estimate for the approved ISS Program including risks and mitigation strategies.

Finding

Judgment of the ISS Management and Cost Evaluation Task Force (IMCE) is that a cost of \$8.3B (FY 02-06) is **not** credible for the core complete baseline without radical reform.

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Cost Credibility, cont.

Rationale

- ISS program management approach
- General observations on ISS management
- IMCE cost review results
- Cost Analysis Support Team results

12

Current ISS Program Management Approach

- Focus on technical excellence and crew safety
- Considerable attention on near-term schedules
- Manage expenditures to ensure FY budget is not exceeded
- Total cost is not a management metric that is used
- Work that cannot be accomplished within FY budget moves to a future FY with little recognition of contribution to total cost growth (schedule becomes a reserve)
- Inadequate management information system and tools being used for program control
- No rigorous cost estimate exists
 - Recent “bottoms up” budget estimate helpful but not sufficient
- Science program is not integrated in the ISS management

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General Observations on ISS Management

- Priority on Fiscal Year management
- Institutional management approach as opposed to project management approach
- Different program baselines being used by various elements of the program

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ISS Staffing and Reporting

	FY02		
	Total Civ Serv	ISS Civil Serv	ISS Contractors
Mission Ops Directorate	454	265	1557
Engineering	814	403	783
Space & Life Sciences	184	31	241
EVA Project	27	19	188
Kennedy Space Center	1835	322	643
Marshall Space Flt Ctr	2692	144	159
ISS Program Office	238	238	3426
Other JSC Organizations	1287	122	790
Glenn Research Center			28
Goddard Space Flt Ctr			15
TOTAL	7531	1544	7828

Program
Direct
Reporting



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IMCE Cost Review Results

- NASA estimate (FY02-06) required for core complete at start of review
- Probable increases identified during review
- Additional concerns
 - Contractor rates
 - International Partner costs
 - Research
 - No common baseline
- Offsets
 - Content changes and rates
 - Operations and sustaining engineering

<u>Budget</u>	<u>Shortfall/Offsets</u>	<u>Reserve</u>
\$8.3B	(\$484M)	\$750M
	(\$366M)	
	(?)	
	\$110M	
	\$330M	
\$8.3B	(\$410M+?)	\$750M

Note: P³ assumed to be separately funded

16

Cost Analysis Support Team Results

- ISS Program Office does not have a robust process to develop cost estimates independent of contractor proposals
- ISS business practices must change to meet OMB budget

17

Requirements to Achieve Credibility

Charter

- Assess program assumptions and requirements and identify options to smaller growth and/or budget savings and efficiencies
- Review ISS Program and financial management, tools, and identified reforms, and make recommendations for improvements.

Findings

Judgment of the IMCE is that the core complete baseline could be accomplished if:

- Major changes are made in how the ISS Program is managed
- Additional cost reductions are achieved in ISS core complete program
- Additional funds are applied to ISS from non-ISS parts of the Human Space Flight budget
- A clearly defined program baseline with a credible "end state" is established

18

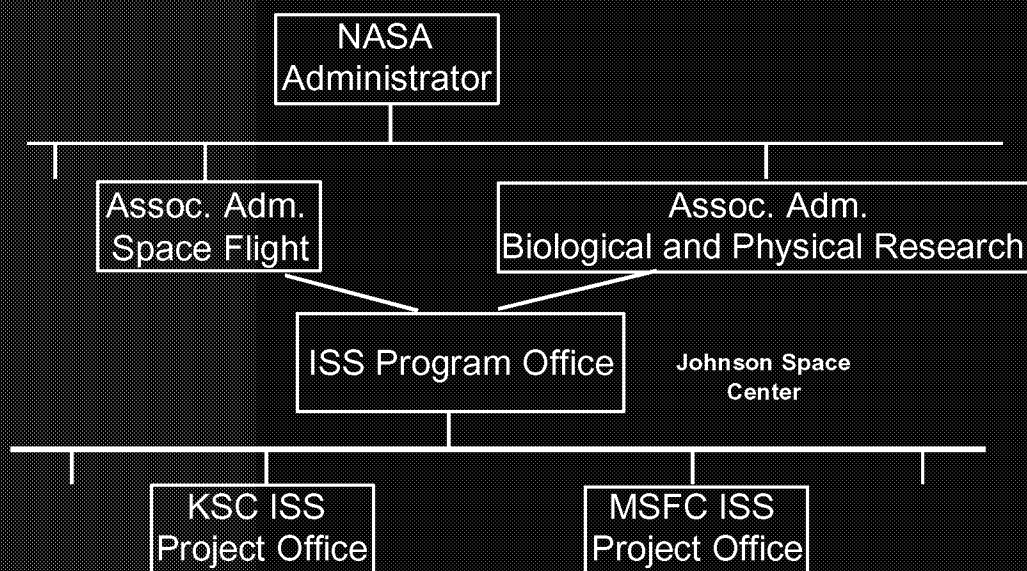
Required Management Changes

- Maintain mission success as Number 1 Priority
- Manage ISS as a program, not an institution
 - All ISS manpower included in program office
 - ISS program manager controls staffing requirements
 - Streamline management reporting and control
 - Program management approach applies to all involved NASA Centers
 - Maintain “checks and balances” to ensure mission success

19

Streamline Management Reporting and Control

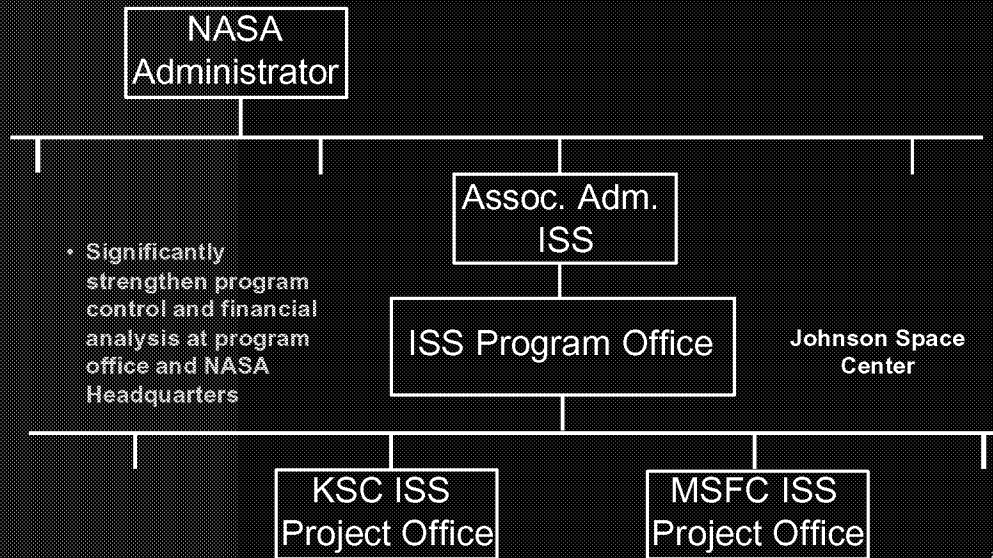
Option 1



20

ISS Management

Option 2 (Recommended)



Required Management Changes

- Consolidate prime and non-prime contracts into minimum number of resulting contracts all reporting to the program office
- Manage to total program cost and schedule as well as FY budgets
 - Develop a technical baseline that can be costed
 - Develop a NASA total cost estimate
 - Use DoD approach
 - Establish management accountability
- Establish a state-of-the-art management information system
 - Existing program control system is highly inadequate
 - No credible plan
 - Ineffective actual vs. plan system
- Strengthen financial and project control function at ISS Program office and NASA Headquarters Associate Administrator

22

Contract Consolidation

Current

Boeing - Prime Contract
26 Non-Prime Contracts



Consolidate to the
minimum number of
resulting contracts

23

Additional Funding Sources

- Incorporate 6-month ISS crew rotation in FY03
- Resulting change in assembly sequence delays U.S. core complete two months to April 2004 and International Partner elements up to one year
- Reduced Space Shuttle flight rate required to support ISS

	FY02	FY03	FY04	FY05	FY06
Current budgeted flight rate	7	5	6	6	6
Revised	7	4	5	4	4
Flights reduced	0	1	1	2	2

24

Additional Funding Sources, cont.

- Cost savings (FY02-06) from change in Space Shuttle flight rate reduction

ISS	\$188M	}	\$668M
Shuttle	\$480M		

- Potential savings (FY02-06) from Strategic Resources Review (SRR)/Institutional reductions

≅ \$350M - \$450M

25

IMCE Cost Review Results

	<u>Budget</u>	<u>Shortfall/Offsets</u>	<u>Reserve</u>
● NASA estimate (FY02-06) required for core complete at start of review	\$8.3B	(\$484M)	\$750M
● Probable increases identified during review		(\$366M)	
● Additional concerns		(?)	
– Contractor rates			
– International Partner costs			
– Research			
– No common baseline			
● Offsets			
– Content changes and rates		\$110M	
– Operations and sustaining engineering		\$330M	
	\$8.3B	(\$410M+?)	\$750M
		≅ \$1.0B	
● Additional resources			
– Assembly sequence and Shuttle flight rate change			
– SRR/Institutional reductions			
	\$8.3B	\$600M-?	\$750M

26

Program Baseline

- Lack of a “defined” program baseline causing confusion and inefficiencies
 - ISS Program was (start of IMCE review) assuming “Program Manager’s” Recommended Program (\$8.3B + \$2.5B) was baseline and core complete was an option.
 - Research hardware element of ISS being implemented as original program.
 - Office of Biological and Physical Research and science community are uncertain.
 - 3-person vs. 7-person crew
 - Centrifuge module ranges from top-priority to cancellation
 - Many assuming 3-person plan is temporary

27

Program Baseline, cont.

- Lack of a “defined” program baseline causing confusion and inefficiencies (concluded)
 - International Partners believe they have been told original program is the baseline and they have “Treaty level” commitments.
 - Crew Return Vehicle (CRV) team assuming funding to continue at a reduced level
 - Etc.

28

Program Baseline, cont.

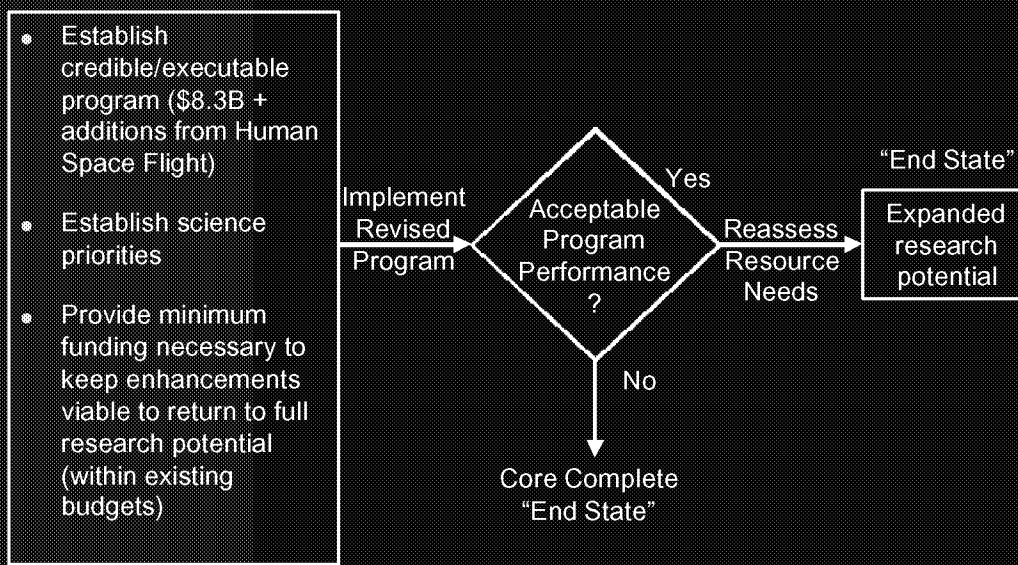
- Options
 - Core complete as “end state”
 - 3-person permanent crew for life of ISS
 - Adverse science implications
 - Adverse International Partner implications
 - Original program as “end state”
 - Provides unique research potential of ISS
 - Requires additional NASA funding
 - Inconsistent with OMB and Congressional ISS credibility issues with NASA
 - Core complete with NASA performance gates leading to “end state”
 - End state defined by science priorities to achieve expanded research potential
 - NASA performance becomes critical to future of ISS
 - Opportunity provided to achieve unique research potential of ISS

29

ISS “End State”

11/01 - 6/02

Fall CY 2003



30

Maximize Research

Charter

Identify opportunities for maximizing research within the planned ISS budget.

Findings

Research management requires significant changes to maximize return within a given budget.

31

Maximize Research, cont.

Current Status

- Research (facilities, utilization, operations, and Mir) budget

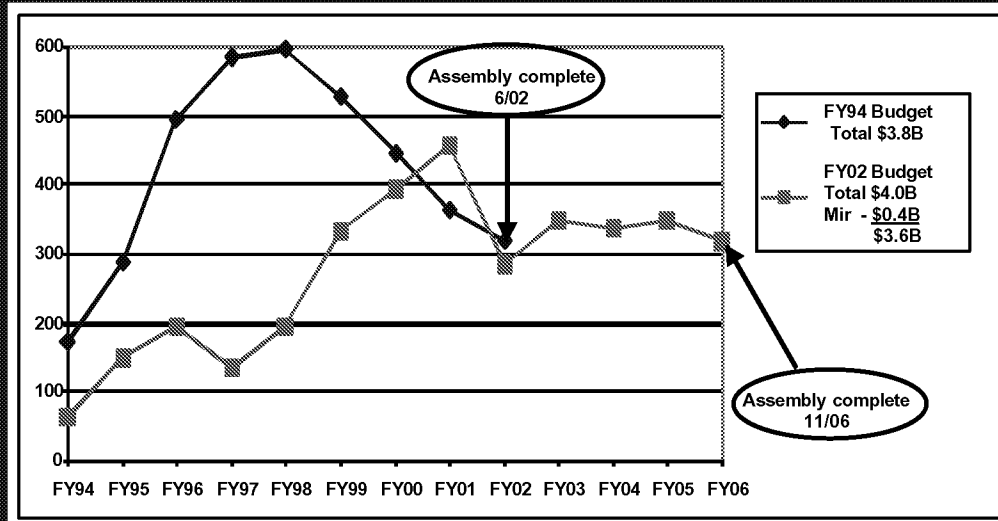
FY 2002	\$4.0B
FY 1994	\$3.8B

Buying power reduced 40%
- Science program is not effectively integrated in the ISS management
- Research implementation is proceeding assuming original program
 - No defined science priorities
 - Critical hardware very late
 - Insufficient research reserve
 - 3-person crew has adverse impact on science that can be performed

32

ISS Research Budget History

Excluding Mir Support Funding
(\$M)



33

Maximize Research, cont.

Recommendations

- Establish science priorities
 - Give highest priority to research directed at solving problems associated with long-duration human space flight including engineering required to support humans in long-duration space flight.
 - The centrifuge is mandatory to accomplish top priority fundamental biology research. Availability as late as '08 is unacceptable.
 - Research in the physical sciences of utmost importance can be accomplished on the ISS.

34

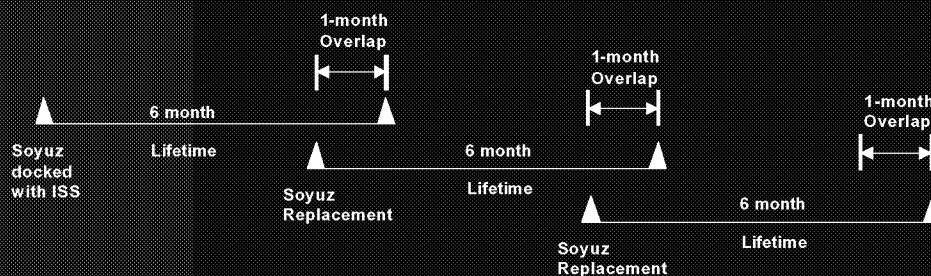
Maximize Research, cont.

- Establish a plan allocating available financial resources consistent with science priorities, including a prudent reserve
- Augment 3-person crew
 - Extended duration shuttle (requires adding shuttle flights if 4 per year flight rate option implemented)
 - Overlap Soyuz missions
- Strengthen science management within the ISS Program

35

Maximize Research, cont.

- Extended duration shuttle
 - Docked time of at least 14 days is feasible
- Overlap Soyuz missions
 - 30 days of 6-person crew every 5 months
 - Cost impact TBD



36

Science Management

ISS Program

- ISS Deputy Program Manager for Science
 - Equal to other deputies
 - Jointly report to Program Manager and AA OBPR
 - Highly respected member of science community with management skills

ISS Program Manager
Deputy for Science
Deputy for Technical
Deputy for Operations

```
graph TD; A["ISS Program Manager  
Deputy for Science  
Deputy for Technical  
Deputy for Operations"] --- B[ ]; A --- C[ ]; A --- D[ ]
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- Science Steering Group (SSG) Chaired by Deputy Program Manager for Science
 - Members from ISS-related science disciplines
 - Meets frequently (at least monthly)
- Science Teams
 - Chaired by member of SSG
 - Members from the science community

37

Enhancements

Charter

Assess cost estimates for potential U.S.-funded enhancements to the core station and recommend refinements as necessary to achieve high confidence estimates

Enhancement options to sustain 6 or 7 person crew

- A- Node 3, US ECLS, 2nd Soyuz
- B- Enterprise (RS ECLS, 2nd Soyuz)
- C- Node 3, US ECLS, ASI Hab, CRV

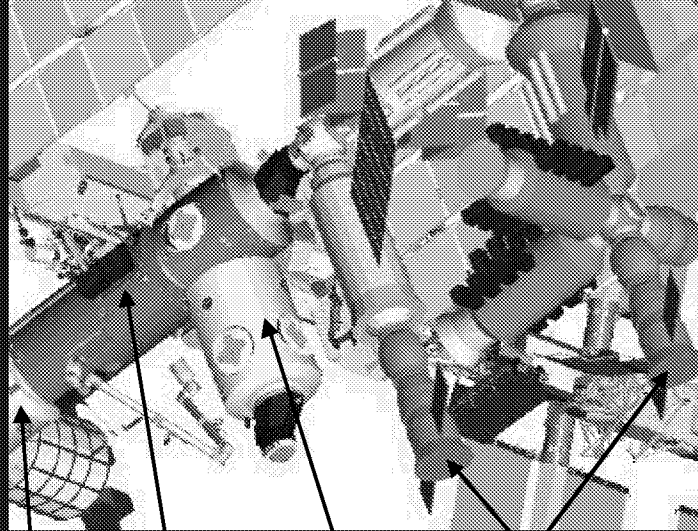
Findings

Cost estimates for U.S.-funded enhancement options are not sufficiently developed to assess credibility

- CRV estimate of \$1.3B is plausible with following assumptions:
 - Assumes FY02 start (program interruption could have significant cost impact)
 - Existing component and subsystem contracts remain valid
 - 3-year on orbit lifetime is not a significant problem
 - Prime contractor accepts X-38 contributions

38

A - Node 3, US ECLS, 2nd Soyuz



Node 2
Crew Quarters

Lab
Galley

**Node 3
US ECLS**
Oxygen Generation (O2 gen.)
Carbon Dioxide Removal (ARS)
Toilet (WHC)
Water/Urine Processors

Soyuz

FY 02-06

≡ \$0.5B

39

B - Enterprise (RS ECLS, 2nd Soyuz)



Node 2
Crew Quarters

Lab
Galley

**Enterprise
Russian ECLS**
Oxygen Generation (Electron)
Carbon Dioxide Removal (Vozdukh)
Toilet

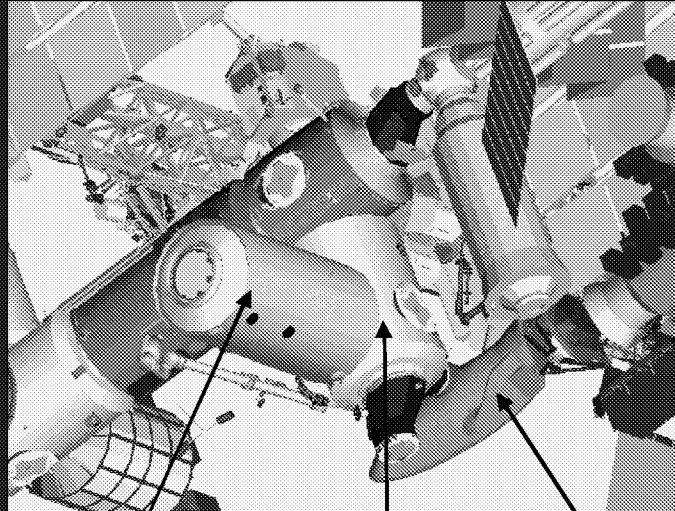
Soyuz

FY 02-06

≡ \$0.5B

40

C - Node 3, US ECLS, ASI Hab, CRV



FY 02-06
≅ \$1.1 B

Assumes

- Italians fund ASI Hab
- ESA funds \$0.5B for CRV

ASI Hab
Crew Quarters
Galley

Node 3
US ECLS
Oxygen Generation (O2 gen.)
Carbon Dioxide Removal (ARS)
Toilet (WHC), Water/Urine Processors

CRV

41

Summary

- ISS core complete program is not credible for cost of \$8.3B (FY02-06).
- ISS core complete program could be credible with major changes including significant staff reductions.
 - Caution:** NASA Human Space Flight “way of doing business” will be difficult to change to the degree required.
- Research management requires significant changes to maximize return within a given budget.
- A program baseline that includes expanded research potential as the “end state” maintains the unique research potential of ISS.

Requires: NASA to demonstrate credibility as a prerequisite to proceeding beyond the core complete program.

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6.0 Appendices

APPENDIX A: ISS MANAGEMENT AND COST EVALUATION TASK FORCE TERMS OF REFERENCE

ISS MANAGEMENT AND COST EVALUATION TASK FORCE

TERMS OF REFERENCE

These Terms of Reference establish the International Space Station (ISS) Management and Cost Evaluation (IMCE) Task Force of the NASA Advisory Council (NAC). The IMCE Task Force is chartered to perform an independent external review and assessment of cost and budget and provide recommendations on how to ensure that the ISS can provide maximum benefit to the U.S. taxpayers and the International Partners within the Administration's budget request.

In addition there are reviews of the ISS financial management tools being conducted by the IMCE Financial Management Team (FMT) to identify and recommend Agency-wide improvements in these tools. The report of the FMT will be integrated into the report of the IMCE Task Force.

The integrated final report is to focus specifically on the following items:

- Assess the quality of the ISS cost estimates for approved the ISS Program, including identification of high-risk budget areas and potential risk mitigation strategies.
- *Ensure that the program can remain within its available budget, assess program assumptions and requirements – specifically those that led to significant cost growth relative to FY 2001 budget estimates – and identify options for smaller growth and/or budget savings and efficiencies that offset any additional spending recommended by the Task Force and approximately \$500 million in unfunded cost growth.*
- Review the management reforms in the ISS Program Management Action Plan -- particularly cost estimating and reporting issues, early warning of potential growth, and managing program reserves – and make recommendations for additional and/or refined management reforms. Integrate results from the FMT.
- Identify opportunities for maximizing capability to meet priority research program needs within the planned ISS budget and International Partner contributions.
- In addition, assess cost estimates for potential U.S.-funded enhancements to the core station (e.g. providing additional crew time for enhanced research) and recommend refinements as necessary to achieve high-confidence estimates.

The Chair and the Members of the IMCE Task Force are appointed by the Administrator. The Chair of the IMCE Task Force will be a member of the NAC. Membership will be comprised of nationally recognized experts who have extensive experience in the disciplines of contracting, procurement, estimating, cost analysis, engineering, scientific research, and program management for complex, high-technology and space-based programs for Government and industry and who are external to NASA. The Task Force will consist of 15-20 members providing specific expertise as appropriate. In addition, the Task Force will be supported by an ISS Cost Analysis Support Team that will provide detailed budget assessments and offset options. The term of membership is for the duration of the Task Force. Members and, where appropriate, members of support teams will be appointed as Special Government Employees; all members and members of support teams will be external to NASA.

MEETINGS

The Task Force will meet approximately three times in formal session and meet in organizational or fact-finding sessions as required. Support teams may meet more often as necessary.

ISS INTERNATIONAL PARTNERS' OBSERVERS

The ISS International Partners are invited to provide observers to participate in the Task Force's formal sessions, which are open to the public. Due to the use of sensitive budgetary and proprietary information during the Task Force's internal organizational and fact-finding sessions, participation by the International Partners may be limited to specific internal sessions.

REPORTING

The Task Force will report its findings and recommendations to the NAC, which will consider and formally present its recommendations to the NASA Administrator for an official Agency response.

ADMINISTRATIVE PROVISIONS

The Executive Secretary will be appointed by the Administrator and will serve as the Designated Federal Official.

The Office of Space Flight will provide staff support and travel funds for the Task Force and its support teams.

DURATION

The Task Force will provide its final report to the NAC by November, 2001.



A BLUEPRINT FOR NEW BEGINNINGS

A RESPONSIBLE BUDGET
FOR AMERICA'S PRIORITIES

33. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Highlights of 2002 Funding

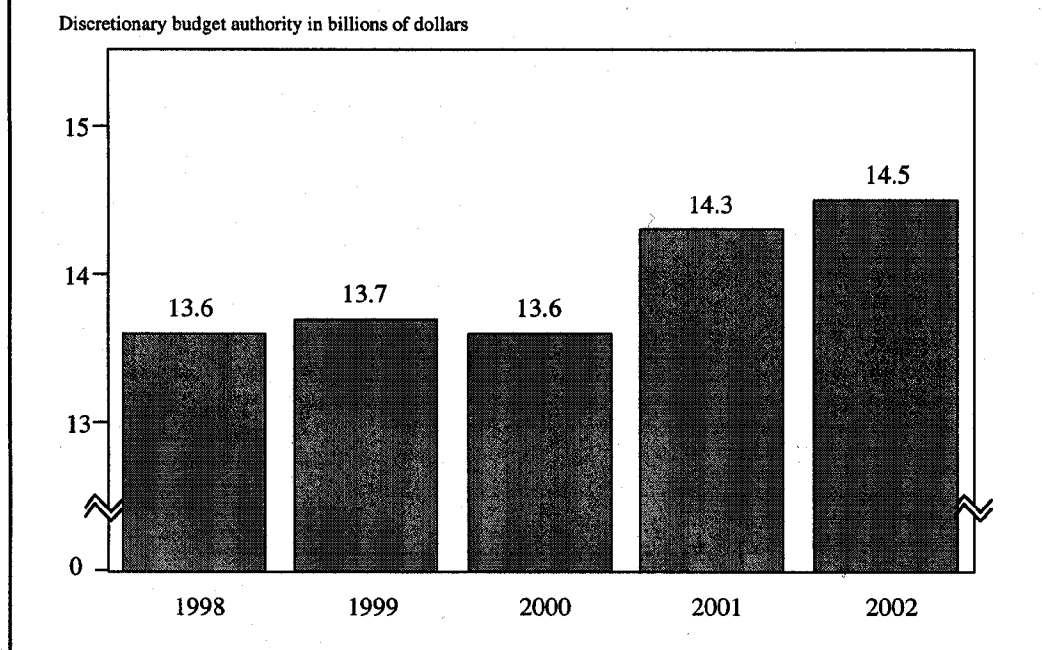
- Provides \$14.5 billion for the National Aeronautics and Space Administration (NASA), a two-percent increase over 2001 and a seven-percent increase over 2000.
- Provides increased funding for International Space Station development and operations consistent with a strategy of constraining Space Station cost growth. Growth in development and operations is largely offset through budget reductions in Space Station hardware and other Human Space Flight programs and institutional activities. NASA will be undertaking a number of management reforms to bring Space Station costs under control.
- Provides a 64-percent increase over 2001 for NASA's Space Launch Initiative. This increase continues NASA's commitment to provide commercial industry the opportunity to meet NASA's future launch needs and to dramatically reduce space transportation costs and improve space transportation safety and reliability.
- Funds a more robust Mars Exploration Program.
- Funds a science-driven program of prioritized follow-on missions for second-generation Earth Observing System measurements that will provide a greater understanding of how the Earth and its climate are changing, an increase of five percent over 2001.

Initiatives and Redirected Resources

International Space Station: Recent cost growth on the Space Station is estimated at approximately \$1 billion for 2001 and 2002 and \$4 billion for the next five years. To address this unprecedented cost growth and ensure that the program remains within the five-year budget plan, the President's 2002 Budget will include important decisions regarding the funding and management of the program while preserving the highest priority goals: permanent human presence in space, world-class research in space, and accommodation of international partner elements. Thus, the U.S. core will be complete once the Space Station is ready to accept major international hardware elements. The cost growth is offset in part by

redirecting funding from remaining U.S. elements (particularly high-risk elements including the Habitation Module, Crew Return Vehicle, and Propulsion Module). In addition, funding for U.S. research equipment and associated support will be aligned with the assembly build-up. Future funding decisions to develop and deploy any U.S. elements or enhancements beyond completion of the U.S. core will depend on the quality of cost estimates, resolution of technical issues, and the availability of funding through efficiencies within the 2002 Budget runout for Space Station or other Human Space Flight programs and institutional activities. The budget will propose advance appropriations for the Space Station as a further means to cap Station spending—this cap may be adjusted upward if efficiencies and

Chart 33-1. National Aeronautics and Space Administration
1.5% Average Annual Growth, 1998-2002



offsets are found in other Human Space Flight programs and institution.

Space Science: To ensure successful execution of programs already underway, two projects with a very large escalation in cost, the Pluto-Kuiper Express and Solar Probe missions, will not be funded. To support a potential, future sprint to the planet Pluto before 2020, additional funds will be directed to key propulsion technology investments. The budget funds a more robust Mars Exploration Program and provides critical technology funding to support future decisions on high-energy astrophysics missions.

Earth Science: NASA has worked with the National Academy of Sciences to develop future Earth Science research priorities and, based on these priorities, has developed plans for the second generation of Earth Observing System (EOS) satellites. NASA's outyear plan for these satellites has been underfunded in recent years, but the budget will provide a

five-percent increase in 2002 for a science-driven EOS Follow-On program while discontinuing low-priority remote sensing satellite and environmental application projects to ensure that EOS priorities can go forward.

Space Shuttle: The budget provides for a sustained level of six Space Shuttle flights per year and continues funding for Space Shuttle safety improvements, within which NASA will establish safety investment priorities for Shuttle safety upgrades and critical facilities.

Aero-Space Technology: The budget eliminates lower priority aeronautics programs and reduces under-performing information technology programs.

Potential Reforms

Fulfilling the President's promise to make Government more market-based, NASA will pursue management reforms to promote innovation, open Government activities to competition, and improve the depth and quality

of NASA's research and development (R&D) expertise. These reforms, described below, will help reduce NASA's operational burden and focus resources on Government-unique R&D at NASA.

International Space Station: NASA will undertake reforms and develop a plan to ensure that future Space Station costs will remain within the President's 2002 Budget plan. Key elements of this plan will: restore cost estimating credibility, including an external review to validate cost estimates and requirements and suggest additional options as needed; transfer Space Station program management reporting from the Johnson Space Center in Texas to NASA Headquarters until a new program management plan is developed and approved; and open future Station hardware and service procurements to innovation and cost-saving ideas through competition, including launch services and a Non-Government Organization for Space Station research.

Space Shuttle Privatization: NASA will aggressively pursue Space Shuttle privatization opportunities that improve the Shuttle's safety and operational efficiency. This reform will include continued implementation of planned and new privatization efforts through the Space Shuttle prime contract and further efforts to safely and effectively transfer civil service positions and responsibilities to the Space Shuttle contractor.

Space Launch Opportunities: NASA's Space Launch Initiative provides commercial industry with the opportunity to meet NASA's future launch needs, including human access to space, with new launch vehicles that promise to dramatically reduce cost and improve

safety and reliability. NASA will undertake management reforms within the Space Launch Initiative, including: ensuring vehicle affordability and competitiveness by limiting requirements to essential needs through commercial services; creating requirements flexibility, where possible, to accommodate innovative industry proposals; validating requirements through external, independent review; implementing a well-integrated risk-reduction investment strategy that makes investments only after requirements and vehicle options are well-understood, to ensure viable competition by the middle of the decade for Station cargo and crew launch services; ensuring no set-aside funds for non-industry vehicles like the Space Shuttle; and achieving affordable, near-term successes in Next Generation Launch Services and Alternate Access to the Space Station, and integrating these near-term activities into longer-term planning.

Critical Capabilities: U.S. academia and industry provide a rich R&D resource that NASA can tap to strengthen its mission capabilities. NASA will develop an integrated, long-term agency plan that ensures a national capability to support NASA's mission by: identifying NASA's critical capabilities and, through the use of external reviews, determining which capabilities must be retained by NASA and which can be discontinued or led outside the agency; expanding collaboration with industry, universities, and other agencies, and outsourcing appropriate activities to fully leverage outside expertise; and pursuing civil service reforms for capabilities that NASA must retain, to ensure recruitment and retention of top science, engineering, and management talent at NASA.

APPENDIX C: BIOGRAPHIES OF COMMITTEE MEMBERS

Chairman

A. Thomas Young. Mr. Young retired as executive vice president of Lockheed Martin after a career spanning more than 30 years. He had previously served as president and COO of Martin Marietta and president of Martin Marietta's Electronics and Missiles Group. Prior to joining Martin Marietta, he had held positions in NASA including center director, Goddard Space Flight Center; deputy director, Ames Research Center; director, Planetary Program at NASA HQ; and mission director at Langley Research Center for the Viking Program. Mr. Young is the recipient of NASA's highest award, the Distinguished Service Medal, for his work on the Viking Program. He is a Fellow of the AIAA, and of the American Astronautical Society. He is a member of the National Academy of Engineering, and chairman of the National Academy of Engineering Committee on Technology Literacy.

Vice Chairman

Rear Admiral Thomas Betterton. Admiral Betterton, USN (Ret.), is currently a visiting professor for Space Technology at the Naval Postgraduate School, and has been retained as a management and technical consultant by a number of aerospace-related corporations. He holds a master's degree and an engineer's degree from the Massachusetts Institute of Technology. As a naval aviator and designated acquisition professional, he served as a major program manager and the senior Navy official, Director Program C, in the National Reconnaissance Office for over 16 years. He has participated in several study efforts for the Defense Science Board and the Air Force Scientific Advisory Board and was a member of the NASA Advisory Committee for International Space Station. He is a Fellow of the American Institute of Aeronautics and Astronautics. Admiral Betterton retired from active duty in January 1992.

SCIENCE GROUP

Michael DeBakey. Dr. DeBakey serves as Chancellor Emeritus of the Baylor College of Medicine and is on the active staff at the Methodist Hospital of Houston, TX. DeBakey received his bachelor's and medical degrees from Tulane University in New Orleans, LA. He completed his internship and residency at Charity Hospital in New Orleans, and then did a residency in surgery at the University of Strasbourg, France and at the University of Heidelberg, Germany. He has served as advisor to almost every President in the past 50 years, as well as to heads of state throughout the world. Dr. DeBakey continues to devote considerable time to national advisory committees and to consultantships in Europe and the Middle and Far East, where he has helped to establish health care systems. In 1969, President Johnson awarded him the Presidential Medal of Freedom with Distinction. In 1987, President Ronald Reagan awarded him the National Medal of Science.

Robert Richardson. Dr. Richardson is the vice-provost for research at Cornell University and shared the 1996 Nobel Prize for the discovery of superfluidity in the isotope helium-3 (^3He). He received his master's degree in physics from Virginia Polytechnic Institute and his Ph.D. in physics from Duke University (Durham, NC). Dr. Richardson joined the faculty of Cornell

University (Ithaca, NY) in 1967. He became director of the laboratory of atomic and solid-state physics there in 1990.

Richard Roberts. Dr. Roberts is currently the head of the Department of Bioinformatics/Research at New England Biolabs (NEB), which produces restriction endonucleases and other related products for molecular biology research. He is a shared award recipient of the 1993 Nobel Prize in Medicine for the discovery of split genes. Dr. Roberts was educated in England, attending the University of Sheffield where he obtained a B.Sc. in chemistry and a Ph.D. in organic chemistry. His postdoctoral research was carried out in Professor J.L. Strominger's laboratory at Harvard, where he studied the tRNAs that are involved in the biosynthesis of bacterial cell walls. From 1972 to 1992, he worked at Cold Spring Harbor Laboratory, reaching the position of assistant director for research under Dr. J.D. Watson. His laboratory pioneered the application of computers in this area and the further development of computer methods of protein and nucleic acid sequence analysis continues to be a major research focus.

Rae Silver. Rae Silver is Helen L. and Mark N. Kaplan Professor of Natural and Physical Sciences and holds joint appointments at Barnard College, Columbia University, and Department of Anatomy and Cell Biology at College of Physicians and Surgeons at the Health Sciences campus. She is also a member of the Program in Neurobiology and Behavior, which encompasses faculty in Neurobiology and Neurosciences campus-wide. Rae Silver received the B.Sc. at McGill University, Montreal Canada, and the Ph.D. at the Institute of Animal Behavior at Rutgers University, Newark NJ. She serves on the editorial board of several journals, and is a member of the executive board of scientific societies, such as Society for Neuroscience Program committee, and president of the Society for Research in Biological Rhythms. Her work has been featured in educational television programming for NOVA, BBC, and others.

ENGINEERING GROUP

Andreas Acrivos. Professor Acrivos is the Einstein Professor of Science and Technology, Emeritus, at the City College of the City University of New York. He obtained his B.S., M.S., and Ph.D. degrees in chemical engineering from Syracuse University and the University of Minnesota. For the past 40 years, Professor Acrivos has specialized in fluid mechanics and has investigated, theoretically and experimentally, a variety of fundamental problems involving the flow of viscous fluids and the associated heat and mass transfer phenomena. He is a member of the National Academy of Sciences and the National Academy of Engineering, and is a Fellow of the American Academy of Arts and Sciences, the New York Academy of Sciences, the American Physical Society, and the American Institute of Chemical Engineers.

Kent Black. Mr. Black was the first chief executive officer of United Space Alliance (USA). He graduated from the University of Illinois with a bachelor of science degree in electrical engineering (BSEE). During his time with USA, his group was chartered to manage and conduct space operations work involving the operation and maintenance of multi-purpose space systems, including systems associated with NASA's human space flight program, Space Shuttle applications beyond those of NASA, and other reusable launch and orbital systems beyond the Space Shuttle and Space Station. Prior to this, he was executive vice president and chief

operating officer of Rockwell International. Mr. Black was instrumental in the formation of USA as a joint venture company by Rockwell and Lockheed Martin, was appointed CEO in late 1995, and served until mid 1997 when he retired. In 1996, he was elected to the International Academy of Astronautics.

Peter Bracken. Mr. Bracken is the former vice chairman of the ACS Government Solutions Group. Prior to his tenure with ACS GSG, Mr. Bracken spent 10 years at Lockheed Martin, serving as president of the Information Science Group. He was also president of Martin Marietta's Information group. Mr. Bracken was vice president and general manager of Martin Marietta's Electronics Company and president of Martin's Electronics, Information, and Missiles Group. He joined Martin as vice president of Technical Operations for Information and Communications Systems. Prior to his tenure of Martin Marietta, he devoted 25 years to NASA. In his last assignment, he served as director of Mission Operations and Data Systems at NASA's Goddard Space Flight Center. Mr. Bracken is a recipient of the NASA Exceptional Service Medal.

Gregory Canavan. Dr. Canavan is the scientific advisor of the Physics Division of the Los Alamos National Laboratory, where he works on arms control, stability, and remote sensing from satellites, aircraft, and unmanned platforms for defense and scientific applications. He holds a B.S. in mathematics from the USAF Academy, an M.S. and a Ph.D. in applied science from the University of California, Davis, and an MBA from Auburn University. Dr. Canavan is a Fellow of the American Physical Society, and member of the Army Science Board, Air Force Space Command Independent Strategic Assessment Group (ISAG), NASA Earth Systems Science and Applications Advisory Committee, and American Association for the Advancement of Science. He is chairman of the board of directors of the Hertz Foundation for graduate education in the applied sciences. He has previously served as DOE director of the Office of Inertial Fusion; special assistant to the Chief of Staff, USAF; White House Fellow, Office of Energy Policy and Planning; DARPA; and USAF Weapons Laboratory (now AFRL).

Sidney Gutierrez. Mr. Gutierrez is currently director of the Monitoring Systems and Technology Center at Sandia National Laboratories in Albuquerque, NM. He holds a bachelor of science degree in aeronautical engineering from the U. S. Air Force Academy in Colorado Springs, CO, and a master of arts in management from Webster University in St. Louis, MO. He retired from the Air Force as a colonel where he flew the F-15, F-16, T-38 and many other aircraft while serving as a fighter pilot, test pilot, and instructor pilot. Mr. Gutierrez joined NASA as an astronaut in 1984 and served on two space shuttle flights. Following his second shuttle flight in 1994, he joined Sandia National Laboratories. He is president of the Board of Regents of the New Mexico Institute of Mining and Technology, chairman of the of the board of directors of Goodwill Industries of New Mexico, and a member of the New Mexico Space Commission. He served on several NASA committees that reviewed the Radar Mapping Mission prior to its successful flight and is currently a member of the Aerospace Safety Advisory Panel.

Bradford Parkinson. The original program director of the Defense Department's Global Positioning Satellite System (GPS), Dr. Parkinson has a broad engineering background in guidance, modern control, astrodynamics, simulation, avionics, navigation, and software engineering and leads a Stanford research group which is developing innovative uses of the

Global Positioning System for aviation. He is a graduate of the U.S. Naval Academy, received a master's degree in aeronautics and astronautics from MIT, and a Ph.D. from Stanford University. He is a distinguished graduate of the Air Command and Staff College and the U.S. Naval War College. In 1977 he received the Defense Department Superior Performance Award for Best Program Director in the Air Force and retired in 1978 with the rank of colonel. He is a member of the Presidential Commission on Air Safety and Security. Dr. Parkinson is a Fellow of the Royal Institute of Navigation and the American Institute of Aeronautics and Astronautics. He was elected to the National Academy of Engineering and is a member of the American Astronautical Society and the Institute of Electrical and Electronics Engineers.

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APPENDIX D: COST ANALYSIS SUPPORT TEAM (CAST) REPORT

Final Report
of the
Cost Analysis Support Team
on
International Space Station (ISS) Program Costs
to the
ISS Management and Cost Evaluation Task Force

October 31, 2001

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1.0 Executive Summary.

1.1 Background.

In a press release dated July 30, 2001, NASA Administrator Daniel S. Goldin announced the formation of an independent task force to examine the budget and management challenges facing the International Space Station (ISS) Program. The NASA Advisory Council created a Terms of Reference (TOR) officially establishing the charter and composition of the ISS Management and Cost Evaluation (IMCE) Task Force. At the same time a supporting team of cost analysts, named the Cost Analysis Support Team (CAST), was formed to assess the program's cost estimates and report its findings to the Chairman of the IMCE. This report details the findings of the CAST.

1.2 Overview of CAST Process.

While the TOR directed the CAST to perform an independent cost assessment of the ISS program, many had the expectation that the CAST would actually develop an independent cost estimate (ICE). Such an estimate was not possible for two reasons. First, an ICE typically takes 6-12 months to develop. Six months is possible when the program has already developed sufficient and concise documentation of program content that facilitates a cost estimate and has a fully-developed and documented cost estimate itself. On the high end, the process could take as long as 12 months when these documents are not available. After reviewing the program's available documentation, an ICE for the ISS program would clearly take closer to 12 months to complete. Unfortunately, the CAST had only 2 months to complete its work.

The CAST reviewed ISS Program content descriptions, budget exhibits, and cost estimates. Detailed reviews were made of selected cost elements based upon their value and purpose. Unfortunately, the CAST's review was impeded by the unavailability of a documented program office cost estimate or a single point-of-contact that understood the various elements and the derivation of their costs. Unlike past cost reviews of the ISS program, the CAST did not focus on remaining development costs until "assembly complete." Instead, the CAST effort was focused primarily on operations and, to a lesser extent, on research. This change was necessitated because the program under the NASA-OMB agreement is now a permanent 3-crew station, instead of the planned 6/7-crew station, with a projected assembly completion of U.S. modules in February 2004. Therefore, the vast majority of the to-go costs are in operations and research.

1.3 Key Findings.

1.3.1 Short-term Budget Focus vs. Long-term Cost Focus.

Clearly, from the data and presentations provided to the CAST over the last two months, the focus of the ISS program office has been tactical, near-term and budget oriented as opposed to strategic, long-term and cost-based. This emphasis has been driven partly because of the annual budget caps and partly because of the way the program is managed. One symptom of such a focus is the annual increase in the projected cost to assembly complete since the FY98 budget, resulting in the inevitable loss of credibility in the program's cost estimate. In the CAST's view, a shift in the program's management philosophy from one of managing annual budgets and slipping content to

meet them to a longer-term strategy with emphasis on program cost for specifically defined content is needed to restore credibility in its cost estimates.

1.3.2 Lack of Credibility of ISS Program Office Cost Estimates.

The following factors contribute to the lack of credibility of ISS program office cost estimates:

- Instead of having a single cost estimating group coordinating and managing costs, ISS costs are estimated and managed at the Project Leader level, introducing potentially significant variability of underlying assumptions and quality of estimates.
- Because a rigorous cost estimation process is not in place, the ISS program office has not been able to successfully communicate what process it does use to develop cost estimates to those outside the program.
- Inadequate documentation of the program office cost estimates, and their underlying content descriptions and assumptions, greatly impedes outside review. Hence, there is an inclination to assume the estimates are flawed.
- The program office has not collected the necessary cost data consistently across the program by function and type, which is necessary for the accurate projection of future costs.
- NASA's internal review processes reinforce the program's focus on near-term budgets. Both the cost estimation process and the credibility of the result will greatly improve if an independent review team within NASA, supported strongly by NASA top-management, developed periodic but comprehensive lifecycle cost estimates of the program instead of simply reviewing the program's execution to budgets.

1.3.3 Proposed Budget Insufficient without Management Philosophy Change.

The recent "Bottom-Up" estimate revealed an approximate \$4B shortfall between projected ISS funding requirements and the OMB proposed budget for FY02-06. After offsets from canceling further development towards a seven-person crew capability and transferring a portion of the Research budget are counted, there remained approximately a \$500M shortfall. Further offsets and a Program Manager's challenge of \$330M have supposedly closed the shortfall.

It's important to note that the "Bottom-Up" estimate reflects the managerial philosophy of historical Human Space Flight programs (especially the Space Shuttle). This philosophy manifests itself in that sharp reductions in sustaining engineering staffing from development levels do not occur until several years of operations have shown that reductions can be achieved with virtually no risk. Furthermore, since systems onboard the Space Station can be upgraded, replaced, and repaired, the program has chosen to support a sustainment infrastructure for virtually all major Station subsystems. Though many satellites fly similar subsystems for years without an ability to modify or repair them, the CAST did not see any inclination to bring forth options that effectively rethink the sustainment plan. Reassessment of this and other fundamental, and extremely costly, program assumptions will be necessary to enable execution of the program without further schedule slips.

within the proposed budget. Indeed, the Program Manager's challenge to close the shortfall reveals management's belief that a change in philosophy is needed and achievable without affecting safety or appreciably increasing risk to the program. The CAST agrees.

1.3.4 Research Budget De-coupled from ISS.

The remaining portion of the research budget not applied against the \$4B shortfall was transferred from the ISS budget under the Human Space Flight appropriation to the Science, Aeronautics, and Technology appropriation to protect it from being used for development or operations. In effect, this transfer has de-coupled the ISS research program from the overall ISS program. At the time of the CAST review, we noted several disconnects between the research budget, the research content, and the capability of the Station to support that content. For example, research projects contingent upon a seven-person crew are still ongoing despite the change to a permanent three-crew Station. There is a potential for significant changes to the research budget, either up or down, upon resolution of these disconnects.

1.4 Recommendations.

The CAST believes that many interesting trades exist within the ISS program, which have not been presented to NASA management. For example, options to reduce planned capability improvements and risk avoidance associated with different levels of sustaining engineering have not been evaluated to the CAST's knowledge. These potential cost avoidance options could be used to defray the current budget disconnect, and perhaps, offset some of the costs of reaching the desired seven-person crew capability. However, without a solid underlying cost estimate of the entire program these trades cannot be effectively evaluated. Furthermore, the CAST judges the budget for Fiscal Year 2002 to be sufficient to maintain the ISS program toward its goal of a six/seven-person crew with minimal impact to schedule.

Therefore, we recommend that over the next year a credible and defensible cost estimate be prepared for the program with all the supporting documentation. Furthermore, we would like to see an independent review group develop and cost options for the program. These options should then be presented to NASA management as alternatives for achieving desired program goals.

2.0 CAST Organization and Process.

The membership of the CAST included cost analysts from the Department of Defense's Cost Analysis Improvement Group (CAIG), the Air Force Cost Analysis Agency, the Naval Center for Space Technology, NASA's Independent Program Assessment Office (IPAO), NASA's Jet Propulsion Laboratory (JPL), and the MITRE and RAND Corporations. To be certain, the two NASA representatives are not associated with the ISS program office, and did not attempt to steer the group's analyses and assessments. A list of the CAST members is included in Appendix A.

The CAST briefed the IMCE on August 21, listing the following questions as its goals, which were derived from the Terms of Reference (TOR):

- Are current program cost estimates accurate?
- What are the programmatic implications?
- Are there additional opportunities in the program for significant cost savings?
- What can be done to improve future program cost management and reporting?

The IMCE expressed its expectation that the CAST would provide an independent cost estimate (ICE) of the ISS program. However, the CAST replied that such an estimate was not possible within the given time constraint of eight weeks. Additionally, the CAST later discovered a lack of program documentation, especially documentation of previous cost estimates, which would have made it difficult to perform an ICE if given six months time to complete.

The first goal of the CAST addresses the central issue embodied in three of the five major items listed in the TOR for evaluation by the IMCE. To be able to answer this question explicitly, the CAST prepared to review and assess an ISS program lifecycle cost estimate. At the August 21 meeting of the IMCE, the CAST requested NASA provide the following documentation:

- Requirements history (e.g. an Operational Requirements Document as used in the DoD) for the 1993 baseline and subsequent revisions
- Cost estimate history (original plus updated estimates associated with major content changes)
- Annual budget submissions beginning with FY95
- Actual costs realized since FY94

NASA Headquarters was quick to provide the budget history, which included annual expenditures for the previous years. However, the CAST had difficulty communicating with NASA the need to review documentation of the requirements or content of the program. At the October 9-10 meeting of the IMCE, the CAST reported its interim assessment that the ISS program office did not have content-driven cost estimates, but only resource-driven budget estimates. Mr. Tommy Holloway, the ISS Program Manager, disagreed with the assessment and invited the CAST to return to Johnson Space Center (JSC) one more time to view the requirements documentation. The CAST returned to JSC on October 16-18 and sampled several elements of the program's Basis of Estimates.

Although NASA's Comptroller stated at the October 23rd meeting of the IMCE that a cost estimate through assembly complete of the 1993 redesigned Station was accomplished, it was never made available to the CAST team, and apparently has not been updated nor used as a cost management tool. There does not exist a lifecycle cost estimate of the entire ISS program (to include the planned period of ten years of operations following assembly complete).

As the CAST team struggled to communicate its need for understanding the program's content behind the projected budgets for ISS, the team shifted its focus to addressing the final two questions from a broader and more fundamental level. This report summarizes the CAST assessments of the factors leading to the historical cost growth, the ISS program office cost estimating processes, and the ISS research program, and concludes with recommendations designed to strengthen the cost estimating process and restoring credibility to the program.

3.0 Historical Cost Growth.

NASA's original cost estimate to build and assemble the 1993 baseline Station was \$17.4B with assembly complete planned for June 2002. (See Appendix B for a chart of the history of the annual projections.) At assembly complete, the Station was originally planned to be able to support a permanent crew of six persons and last for at least 10 years at an annual cost of \$1.3B for research and operations. So, one could assume that NASA's original lifecycle cost estimate was \$30.4B from 1994 through 2012—the planned life of the Station. It is important to note that this estimate does not include the costs of in-house civilian personnel, principal investigators, or Space Shuttle launch support, which has been a traditional bookkeeping practice with all of NASA's programs. Furthermore, the cost estimate does not include the \$10B spent by NASA (again excluding in-house personnel costs) from 1984 through 1993 on the original Space Station Freedom. In June 1998, before the House Committee on Science, the GAO testified that the total U.S. lifecycle funding requirements for the Space Station would be \$95.6B based on NASA's FY99 budget (GAO/T-NSIAD-98-212). Using the same methodology and NASA's February 2001 budget submission to OMB for FY02-06, a rough estimate is now \$105B.

3.1 Program Assumptions.

The Clinton administration directed the Station redesign in 1993 to reduce the projected cost of Freedom, which was independently estimated at \$3-5B above NASA's March 1993 estimate of \$23.6B. Additionally, the Russians were invited to participate in the program at this time.

Some of the assumptions behind the selected 1993 Space Station "Alpha" design and cost estimate of \$17.4B now appear to be ridiculously optimistic. The failure to realize the following assumptions led to significant cost growth.

- The launch of the first module Zarya (a.k.a. Functional Control Block), an U.S.-owned module built and launched by the Russians, would be in May 1997.
- The inclusion of the Russians would save \$2B off the \$19.4B estimate.
- Implementation of a novel approach called "build and shoot" relying heavily on computer simulation as opposed to rigorous ground testing to integrate the hardware and software of the various elements would be employed to save costs.
- The space flight software would total 500,000 source lines of code (SLOC).

- A sharp de-staffing plan would be implemented as hardware was delivered.

The \$17.4B total budget can be segmented into three major portions: (1) design, development, test and evaluation (DDT&E) of the vehicle, (2) operations and support (O&S) and integration of the vehicle during assembly, and (3) the research program (DDT&E of research facilities, integration and utilization). Any slippage in the date of the launch of the first module, or stretching of the assembly schedule, automatically incurs a penalty cost against the \$17.4B cap in terms of the O&S and research portions of the ISS budget. Both of these events have been realized.

First, the launch of Zarya did not occur until November 1998. Next, the first U.S.-built module, Unity was launched in December 1998. However, the Russian Service Module, Zvezda, was delayed multiple times until it was finally launched in July 2000. The delay in the launch of the 1st module and the 18-month gap between the launching of the 2nd and 3rd modules meant that the assumed \$2B savings by including the Russians in the program would not be realized. By August 2000, the assembly complete date had slipped from June 2002 to April 2006 (46 months) according to the Revision F schedule of the assembly sequence. Using the original estimate of \$1.3B per year for operations and research after assembly complete, the cost growth due to schedule slippage alone is \$5B.

The delayed launch of Zvezda caused NASA to build additional insurance into the program to guard against threats due to Russian nonperformance. These actions became collectively known as Russian Program Assurance (RPA) and included an Interim Control Module and an U.S. Propulsion Module in the event the Russians could not supply the Service Module and propellant logistics flights. By February 2001, the projected total costs for RPA through FY 2006 had grown to \$1.3B.

As the Russian Service Module, Zvezda, was continually being slipped, other U.S.-built hardware was arriving at Kennedy Space Center (KSC) and being readied for launch. The schedule slip permitted additional ground testing to be performed on this hardware, and significant integration problems were discovered that escaped notice during the computer simulations of the hardware and software integration. The ISS program established a more rigorous Multi-Element Integrated Testing (MEIT) program and abandoned its novel and overly optimistic “build and shoot” concept. Still more rigorous stress testing could be performed in addition to these nominal tests. Stress tests are performed only in the ISS Systems Integration Lab (ISIL), a non-flight assemblage, and in simulators at JSC.

The space flight software, originally projected to be about 0.5M SLOC, is now projected to be about 1.5M at completion. Approximately, 0.8M SLOC is on orbit with the current configuration. With each new piece of hardware that is delivered to orbit, more SLOC and upgrades are delivered as well. A cost estimate of the original 0.5M SLOC for space flight software was not examined; however, a simple extrapolation would suggest that development and sustainment costs for the space flight software has tripled. This number does not include the approximately 4M SLOC associated with the Mission Control Center (i.e. flight operations on the ground) and the 2M SLOC associated with the Space Station Training Facility. One can assume that significant growths have occurred in the original SLOC estimates for both of these areas as well.

The introduction of MEIT and the growth in the size of the space flight software are two reasons the ISS program has not followed its original de-staffing plan.

3.2 Introduction of the Crew Return Vehicle.

Another significant item of cost growth introduced to the program in 1997 was the requirement for an U.S.-built Crew Return Vehicle (CRV). This was first reflected in the FY99 budget. Originally, the ISS program planned to use two Russian Soyuz vehicles attached to the Station for emergency crew return after achieving permanent six-person crew capability. NASA estimates that an unplanned return of an injured or sick crewmember or the evacuation of the Station is probable over the planned ten years following assembly complete. Each Soyuz vehicle has a capacity for three persons, and the estimated cost is \$65M per vehicle. Furthermore, a Soyuz vehicle's lifespan on orbit is only six months. Russia currently provides a single Soyuz vehicle every six months since permanent three-person habitation began with the arrival of the first Expedition Crew in November 2000. However, it is not clear that the ISS program included any U.S. cost to provide Soyuz vehicles once six-person crew habitation was attained at assembly complete. Nor is it clear that there is an agreement for Russia to supply Soyuz vehicles beyond the assembly phase, as they would be unnecessary with a CRV on station. Furthermore, HR 1883 limits U.S. ability to purchase goods and services from Russia; that is, there are political constraints to NASA purchasing Soyuz vehicles.

Under the bartering arrangements with the International Partners (Europe, Canada and Japan), there will be times when the U.S. share of a six-person crew will include a non-U.S. member; whereas there will always be three Russians. In 1997, a political decision was made to increase the crew size from six to seven, so that the U.S. would always have three crewmembers (in addition to the three Russians), and the seventh crewmember would rotate among the other International Partners. Additionally, NASA determined that the Soyuz vehicles did not meet the requirements necessary to return an ill or injured crewmember. So, the program introduced the requirement for an U.S.-built CRV capable of returning seven crewmembers in a shirtsleeve environment—the Soyuz vehicle requires the wear of a Russian spacesuit. The estimated cost to build four CRVs is approximately \$1.5B. The planned lifetime on orbit for each vehicle is three years; however, a CRV can be refurbished and reused.

3.3 Managing to Annual Budgets.

Perhaps the single greatest factor in the cost growth of the ISS program has been NASA's culture to manage the program to its annual budgets. At the time that the Clinton administration and Congress approved the redesigned Space Station, annual budget caps of \$2.1B were levied on the program as a means to control costs. In general, such caps establishing level annual funding on a major program are counterproductive to controlling total program cost. Total cost and schedule became variables as NASA's focus became one of executing the program within the annual budgets. Additional funding was requested and provided for the Russian Program Assurance and Crew Return Vehicle; however, program content was continually slipped to the right (and outside the five-year budget windows) to stay within the annual budget caps.

Various budget exercises and shifting of resources have been employed to maintain the annual budget caps. In the period from FY95 through FY01, \$966M in O&S funding and \$980M in research funding were transferred to development within the ISS budget line (based on the FY00

budget structure and the initial funding levels provided in the FY95 budget). In 2000, Congress enacted a new cap of \$25B. This cap is on the accumulated annual funding since FY94 until the year when the funding for development is less than 5% of that year's budget. At the same time, the ISS budget was restructured and the "Operations Capability and Construction" line was moved from development to operations. The estimated cost for this budget line in the FY01 budget through FY05 was \$878M. Finally, the FY01 budget transferred out-year funding of the CRV totaling \$765M from the ISS budget line in the Human Space Flight appropriation to a line in the Science, Aeronautics and Technology appropriation. Both of these budget exercises are clearly associated with the new cap of \$25B.

3.4 Cost Growth since FY 2001 Budget.

Following the Russian launch of the Zvezda Service Module in July 2000, NASA launched eight Space Shuttle assembly missions in the twelve-month period from September 2000 to August 2001. Furthermore, the first permanent Expedition Crew arrived on station in November 2000. Operationally speaking, this period has been a spectacular success for the ISS program. Meanwhile, the ISS Program Manager called for a "Bottom-Up" review of all costs. The November 2000 submission to OMB for FY02-06 totaling \$8.8B incorporated a \$608M increase over the same period with respect to the FY01 budget. The total budget through assembly complete grew by \$2B with the additional slippage of 11 months realized in the August 2000 Revision F schedule (from May 2005 to April 2006). As the "Bottom-Up" review continued, NASA returned to OMB with an updated request for FY02-06 totaling \$12.2B, and the total budget through assembly complete was now \$29.3B (compared to the \$26B estimate three months earlier).

The "Bottom-Up" review exposed the bow wave of content that had been pushed to the right in the vehicle DDT&E (\$1.1B) and the severe underestimation of the operations costs (\$1.9B) now being realized. The remaining \$1B in the \$4B plus-up from the FY01 budget to the February 2001 request for FY02-06 includes \$0.75B for additional reserves and the remainder for RPA.

3.5 Budget Summary.

In summary, the original cost estimate was extremely optimistic. Administrator Goldin's management style of "better, faster, cheaper" permeated the program's redesign. Every element of the Station was pushed during the redesign phase to reduce costs. Content that was removed during redesign has fought its way back into the program.

The recent "cost growth" of \$4B resulted in OMB directing the removal of further development to achieve seven-person crew habitation (U.S. Habitation Module, Advanced Environmental Control and Life Support System, U.S. Node 3, and the U.S. Crew Return Vehicle), elimination of the Russian Program Assurance (U.S. Propulsion Module and Interim Control Module), and a reduction and realignment of the research program. These actions left a \$484M shortfall between NASA's projections and the President's FY02-06 budget.

As the CAST reviewed the budget history, it became clear that with most of the hardware

DDT&E now complete under the NASA-OMB agreement, and the transfer of the research budget from the ISS budget line in the Human Space Flight appropriation to the Science, Aeronautics and Technology appropriation, that we focus on the O&S and research costs.

4.0 Operations and Support Costs.

Station operations costs began to exceed vehicle development costs in FY01 and will dominate future ISS budgets. Furthermore, NASA's estimate of the operations costs has grown dramatically and represents nearly half of the \$4B in cost growth for FY02-06 since the FY01 budget. Table 4-1 summarizes the operations costs estimates since the FY01 budget.

Table 4-1. Operations Cost Estimates (\$ Millions)

	FY02	FY03	FY04	FY05	FY06	Total
FY 2001	786	778	728	723	720	3735
Nov 00	801	793	809	835	780	4018
Feb 01	1268	1186	1096	1018	1001	5570
Aug 01	1359	1273	1108	1052	1001	5792

In an attempt to validate a sample of the operations costs, the CAST team reviewed requirements documentation and bases of estimates for several elements of the operations costs, performed parametric crosschecks, and reviewed a NASA model for estimating Station operations costs.

4.1 MESSOC.

The operations budget values were compared with the results of the Model for Estimating Space Station Operations Costs (MESSOC) estimating model (see Appendix C for an overview of the model). The model represents the cost of operating the ISS based on historic business practices and operating procedures. The cost estimating relationships (CERs) and algorithms used in MESSOC were developed using NASA actual cost data or accepted CERs. For many of the logistics and operations modules, especially dealing with training, spares, and repairs, Air Force and Navy CERs and algorithms were used. MESSOC does not make annual adjustments to the coefficients in some CERs since it assumes that operations are already mature. For example, the percent of sustaining engineering used cannot be changed as the Station gets older. For hardware replacements in ground facilities, annual adjustments are made that depend on the age and type of each facility's capital stock. The re-invention and re-engineering initiatives that the ISS program office is implementing are not reflected in the current version of the MESSOC model.

The value of the model is to demonstrate the cost of operating the ISS based on NASA standard and historical business practices. The MESSOC estimate of the annual operating costs for the Space Station after assembly complete of the planned seven-crew station is approximately \$1.19B beginning in FY07 (using FY07 dollars). This is almost 24% greater than the August 14, 2001 Program Manager Recommended budget of \$958M for FY07, but the MESSOC estimate includes the full costs of civilian personnel and CRV O&S.

4.2 Training.

The ISS program office is required to “provide training for instructors, ISS crews, and flight controllers in accordance” with various NASA and ISS requirements and program documents. A sample list of requirements and program documentation impacting the training program is provided in Appendix D.

The training cost estimates were developed by the program office, are content driven, and based on either actual costs or current rates. The estimating methodology was algebraic in nature and is reasonable with a high degree of credibility.

The total number of students and skill sets drives the ISS training costs. These cost drivers are outside the training managers control; however, the training manager is taking steps to reduce the length and cost of the training, especially for the ground crew, by modifying the program to create generalists, capable of working multiple positions rather than specialists. This will reduce total crew size requirements and the variety of curriculum required.

4.3 Avionics.

Avionics includes DDT&E, procurement, integration, and operation of avionics hardware and software for the ISS. The avionics cost estimates are developed by the Prime Contractor (Boeing) and then assessed by the ISS program office for reasonableness and conformity with the current budget. The Program Manager uses the term “smart buyers” to refer to government personnel with technical backgrounds and experience in other NASA space programs who are used to evaluate contractor estimates. The credibility of the methodology is questionable since the ISS program office did not perform a government cost estimate for avionics.

Maintenance cost estimates for avionics hardware developed by Boeing used a bottom-up methodology based on man loading to meet the various tasks listed in the statement of work (SOW) and the applicable NASA and ISS requirements and program documents. The ISS program office assessed the estimates for reasonableness based on engineering judgment. A performance measurement system for tracking historical costs to estimates was not provided. The annual maintenance costs represent approximately 10% of the total DDT&E costs for the avionics hardware as compared to 2% for industry and DoD. However, this 2% figure is based on the total procurement buy, which for DoD can involve dozens if not hundreds of systems, so a larger number is probably warranted for the ISS. A more detailed analysis should be performed to determine what tasks could be removed from the SOW, and an independent cost estimate should be developed for those tasks.

Estimates for spares and maintenance developed by Boeing used existing logistics CER methodologies based on assumptions about input variables, such as Mean Time Between Failure (MTBF) and maintenance schedules, provided by the program office. It is not clear how the input variables were determined.

4.4 Thermal & Environment Control Systems (TECS).

Boeing developed the cost estimates for DDT&E, procurement, and integration and operation of the TECS. The basis of estimates relies upon the SOW and program documents, which are reviewed by the ISS program office and negotiated. The credibility of the methodology is questionable without a government cost estimate.

The basis of the current Boeing estimate for DDT&E are earned value assessments, which were determined by the contract value. The I&O estimate is based on historical task order estimates and adjusted based on remaining assembly sequence and on-going flight tasks. Many of the individual task items are based on extrapolations of previous budgets. All the elements could be related to specific SOW requirements and were assessed by the program office for reasonableness. However, the responsible engineer or manager mostly used engineering judgment of the task and the previous years' effort to make the assessments. Estimates for spares and maintenance developed by Boeing used existing logistics CER methodologies based on assumptions about input variables, such as Mean Time Between Failure (MTBF) and maintenance schedules, which are provided by the program office. It is not clear how the input variables were determined.

4.5 Mission Operations.

Under the Space Flight Operations Contract (SFOC) the ISS program is provided Flight Control, Flight Preparation, Flight Software, and Planning and Analysis for all ISS missions. The tasks are estimated based on man loading for the various tasks under the contract. The manning requirements are based on the various NASA and ISS requirements and program documentation.

The mission operations cost estimates were developed by the program office, are content driven, and based on either actual costs or current rates. The estimating methodology is reasonable and credible. NASA has extensive experience and historical data on operations costs to support human space flight.

Engineering managers recognize that the recurring operations costs are an area for re-invention and re-engineering, since many of the tasks are repetitive. Current plans are to begin reducing tasks (requirements) after two to three years of stabilized operations.

4.6 Systems Engineering and Integration (SE&I).

The SE&I cost estimates are based on man loading for the various tasks within the ISS effort. The basis of estimates relies upon the SOW and program documents, which are reviewed by the ISS program office and negotiated. The credibility of the methodology is questionable without a government cost estimate.

4.7 Launch Operations Support.

Kennedy Space Center (KSC) launch operations costs were estimated based on the current assembly launch manifest and interface control documents. These costs are for the ISS payload-unique integration costs and do not include recurring (standard) integration. Government personnel using the current SFOC contract rates develop the launch operations cost estimates. KSC has over 20 years of experience interfacing and integrating payloads onto the Space Shuttle. This experience forms the basis of hours/man-loading required for the different payload segments. While the estimating methodology is reasonable, only in the last year has KSC implemented a performance measurement plan to track actual hours with estimates for launch operations support. This effort should identify areas for further cost savings.

4.8 Software Maintenance.

The ISS program office uses a simple parametric model to estimate the number of equivalent persons (EP) necessary to maintain software by Computer Software Configuration Item (CSCI). The CAST reviewed a single CSCI from each of the three major areas of software development: NCS R2 for Flight, the command server (CMD SVR) for the Mission Control Center (MCC), and the onboard computer emulator (OBCE) for the Space Station Training Facility (SSTF). Then we developed crosschecks of the EP estimates to maintain these CSCIs using two separate models (SEER and PRICE). The estimated source lines of code (SLOC) for Flight, MCC and SSTF software are 1.5, 4.0 and 2.0 million respectively. Table 4-2 summarizes the results.

Table 4-2. EP Estimates of Selected CSCI

CSCI	SLOC	ISS	PRICE	SEER
NCS R2	133K	6 EP	4 EP	13 EP
CMD Server	567K	9 EP	?	56 EP
OBCE	250K	9 EP	9 EP	40 EP

In general, the PRICE estimate of EP requirements was close to the ISS estimate for each CSCI examined (data for one was not complete) whereas, the SEER estimates were all significantly higher. A more detailed analysis should be accomplished to determine the factors leading to the different estimates by the two models.

Additional CSCIs from Space Flight software were evaluated using SEER to check for consistency of the estimates. Data for the PRICE model were not immediately available. The results are summarized in Table 4-3.

Table 4-3. EP Estimates of Selected Space Flight CSCI

CSCI	SLOC	ISS	SEER
NCS R2	133K	6	13
INT	42K	19	3
N3SYS	22K	5	2
HCS	97K	16	9
S3/P3	36K	7	13
N2SYS	32K	8	2
EXT R1	96K	26	9
TOTAL	458K	87 EP	51 EP

The SEER model estimates 41% fewer EP required to maintain the above CSCIs than does the ISS program office. This preliminary analysis reveals an area for potential cost savings that can

be applied to other areas of the program. A more detailed analysis should be conducted and expanded to include software maintenance for the SSTF and MCC as well.

More importantly, use of any of these models is not the best estimating methodology at this stage of software development. All of the models rely upon subjective input factors and are designed to project resource needs for the average or typical project. Higher confidence in model projections can be attained if the model is calibrated to the specific requirements of the software program. Such models are appropriate prior to or at the beginning of software development, before actual data is available. Instead, the program office should be using actual data (e.g. productivity rates, failure rates) to estimate the EP needed to maintain software at this point in the program. Although failure rates are being tracked, we did not examine whether or not the program office has been collecting actual productivity rates throughout development.

4.9 Operations and Support Costs Summary.

O&S costs are estimated to be around \$1B after assembly complete of the seven-crew station and represent an area where significant cost savings may be achieved (as revealed by the crosschecks CAST performed for the avionics and software maintenance costs). An independent government agent should review ISS operations requirements in detail, and then a government cost estimate should be developed for these requirements.

5.0 Research Budget.

The currently proposed ISS Research Budget for FY02-06 (\$1.634 B), realized in the NASA-OMB agreement, reflects an anticipated elimination of identified cost content. This top-level budget exercise has not been supported by effort to insure the validity of the total figure. The remaining content has not been scrutinized to reconcile it with the overall ISS budget reductions that may result in reduced research capability. Contract terminations of eliminated budget content have not been initiated in a manner that will insure proper budget execution. The inclination toward inaction has been sustained by an attitude that assumes that Congress may increase the President's Budget for eliminated content. The inaction has precluded the development of a realistic acquisition strategy and the potential identification of excess funding that could be diverted to the realization of the original ISS goals.

There is a potential for cost increases associated with the development of ISS research racks and attrition-related costs associated with the manning of the Payload Operations Facility at Marshall Space Flight Center. A strategy of redesigning payloads to accommodate remote or automated operation would also result in additional cost.

Cost determinations of the potential increase or decrease could not be made within the time frame allotted to this review due to the nature NASA's financial management structure. It does not readily facilitate analysis of cost data that would allow validation of budget determinations.

5.1 Reconciliation of Budget, Content and ISS Capability.

The budget reduction exercise appears to have focused on eliminating content to achieve the budget mark. It is not apparent that effort had been made to reconcile the budget mark with

remaining content, as it may be impacted by overall reductions to the ISS budget. The primary impact of concern is an increasing reality that the ISS may be limited to a three-person crew versus a six or seven-person crew. NASA maintains that this is not a near-term concern because the planned seven-person crew capability does not become a reality until a period after the current budget window. We reject this argument noting that NASA will begin funding development of research payloads anticipating the seven-crew complement as early as FY03.

5.1.1 Budget.

The current budget mark appears to be an arbitrary reflection of content. As noted, it does not appear to have been adequately reconciled to anticipate potential changes to the physical and operational characteristics of the ISS. It lacks the cost fidelity that would allow a determination of adequacy. This is particularly critical in determining cost risk. Areas of potential risk are addressed in Section 5.3.

The most significant failing of the proposed budget is the lack of a coherent financial management strategy attributable to the stand-alone research budget, and more importantly, the budget as an integrated part of the total ISS effort. There are indications that the proposed content may exceed the operational capabilities of the ISS. If this is true, management should be aggressively evaluating the potential for re-planning and redirecting budget.

5.1.2 Content.

NASA achieved the current budget mark by reducing content. It did not address the nature of the remaining content or the potential implications of the ISS not developing to a six or seven-person crew capability. It rationalizes this approach under the assumption that operation within the budget window (FY02-07) will be conducted with a three-person crew. NASA has, however, acknowledged that it will begin funding development on out-year payload profiles as early as FY03. This includes payloads that anticipate six or seven-person crews. There was no indication that NASA had considered the operational and cost implications of the three-person scenario or the potential for realizing cost reductions if this scenario becomes reality. It would also appear, given the FY03 investment implications, that the decision is time critical.

Furthermore, the budgeted content may have unaccounted risk that could be an added cost. Realized crew capability may be less than anticipated, which could result in unattended payloads. It has been suggested that remote or automated operation could remedy this situation. This remedy has design and related cost implications, which are not considered in the budget.

5.1.3 ISS Capability.

It does not appear that an in-depth analysis has been conducted with respect to the realized and emerging ISS capability. As noted above, three-person crew accomplishments have not met expectations. Expedition 1 realized three complete and one partial completion of five planned experiments. Expedition 2 realized 15 completions, two partial completions, and a failure. Crews required an additional one to two hours per day to accomplish the daily workload. It is anticipated that as more Station hardware is integrated on orbit (especially the additional European, Japanese and Russian labs) that this problem will be exacerbated.

The research scenario is predicated on an allotment of 20 crew hours per week for a three-person crew. The adequacy of this allotment relative to the identified research content could not be established during this review. The ability to support this allotment is suspect. It is further complicated by International Partner claims that could be altered due to the budget-related impacts. These are not yet well understood, but could well erode U.S. research claims on the crew allotment.

There are also potential up-mass limitations created as a result of additional Space Shuttle manifest requirements. These occur due to reductions in Russian support. These limitations are considered a secondary threat, but do require further analysis.

The most likely mitigating scenario would be implementation of a six or seven-crew capability. This does not appear likely, given the ISS budget implications. Given the implication, it is frustrating to note that the above mentioned disconnects point to an over-funded research program. This can only be ascertained through a rigorous reconciliation of budget, research content, and ISS capability. That recognition could lead to a reprioritization of funding directed at achieving a robust crew compliment and the envisioned science program.

5.2 Organizational Disconnect.

There are apparent communication disconnects between the NASA Research functional directorate (Code U), the ISS program office and the field center research implementing organizations. This has led to the lack of budget reconciliation and an integrated financial management strategy.

5.2.1 Research vs. ISS Program Office.

The research approach appears insular. It appears to lack coordination with the emerging reality imposed by ISS budget reductions. It is not part of an integrated financial management strategy and, ultimately, may be frustrating the development of a robust science program.

5.2.2 Headquarters vs. Field Implementing Activities.

A similar disconnect exists with field implementing activities. This has led to unclear budget direction regarding the new priorities that are emerging as a result of the budget reductions. This lack of direction has led to a continuance of expenditure that cannot be sustained under the revised budget mark.

5.2.3 Budget Mismanagement.

This is best exemplified by a failure to execute timely termination on contracts supporting activities that have been identified for elimination in the revised research budget. Consequently, NASA continues to incur costs for contract activities that are now outside the budget scope. This guarantees that field activities will exceed their near-term budget authority.

NASA has advised that terminations can occur only with congressional approval. It does not appear that such approval was sought in a diligent manner. It does appear that NASA, instead, was looking to Congress to reinstate funds. While this may be a practical political maneuver, it cannot be considered practical financial management.

5.3 Cost Risk.

There are areas where NASA is exposed to cost risk associated with the identified budget. This occurs in Payload Rack development, Payload Operations, and Remote/Automated Payload operation.

5.3.1 Payload Rack Development.

Complex payload racks are still in development. The individual racks are budgeted at \$80 million. Cost data or bases of estimates were not readily available to determine adequacy. The nature of the development would indicate moderate cost risk and a potential budget threat.

5.3.2 Payload Operations Facility.

This is now, essentially, a fixed cost due to staffing reductions. Current staff is considered minimal. The staffing profile establishes the potential for higher than anticipated attrition. If such attrition is realized, it is anticipated that the cost of replacing and training staff would exceed current budget estimates and could impact operation capability.

5.3.3 Remote/Automated Payload Operation.

Remote and/or automated payload operation has been suggested as a means of alleviating reliance on a smaller ISS crew. This would, however, necessitate redesign of payloads and incorporation of technology to support such operations. This would result in added cost. The cost would be dependent on stage of development. Higher cost would be associated with payloads in advanced stages of development. There is also the potential to shift additional cost to sponsors or the Payload Operations Facility.

6.0 Recommended Management Changes.

The ISS Program and NASA in general, have a long-established culture of managing programs to annual budgets. We make the following recommendations to bring greater cost discipline to the program.

6.1 Establish an ISS Cost Analysis Group.

The ISS Program needs to establish a Cost Analysis Group to perform the following tasks:

- Lead development of a single requirements document for cost-estimating purposes
- Develop a baseline “full cost” lifecycle cost estimate for the program
- Maintain the lifecycle cost estimate through program changes
- Perform cost analyses to enable program requirements tradeoffs

- Develop contractor cost reporting requirements and monitor periodic reports
- Report regularly to ISS program management on program costs
- Provide visibility into program costs to outside agencies

6.2 Strengthen Oversight of Inter-center Transfer Agreements (ITA).

ITAs will become a greater percentage share of the ISS budget in future years. There is currently no program-wide guidance on generating ITA estimates. The ISS program office relies upon each center to manage its share of the budget once the money has been delivered. There needs to be greater oversight of ITA cost estimates and performance. The establishment of a standard accounting and financial management system across all NASA centers is a necessary tool to enable such oversight.

6.3 Implement Full Cost Accounting.

In response to internal direction and Federal legislation (e.g. 1990 Chief Financial Officers Act, the 1993 Government Performance and Results Act and the 1996 Federal Financial Management Improvement Act), NASA began a Full Cost Initiative in April 1995. To date, NASA has not yet implemented a Full Cost Accounting system. NASA needs to make the commitment to implement such a system to eliminate the problems associated with its nonstandard, decentralized accounting systems that do not regularly capture certain cost information.

6.4 Request an Independent Cost Estimate.

The program has undergone multiple reviews (both internal and external), but has failed to achieve any real cost discipline. NASA should require the development of an independent cost estimate (ICE) for the ISS program that should be updated periodically (biennially) by a group outside the ISS program office. This estimate should be used when making major programmatic decisions. An ICE should be started immediately to be ready by FY03.

7.0 Summary.

The ISS Program is arguably the largest and most complex program NASA has ever undertaken. Given the program's size, complexity, and the challenges associated with integrating systems contributed by the International Partners, no one should be surprised that the program has realized significant cost growth. Many factors have contributed to the cost growth, and several of these have been outside the control of the Program Manager. However, the Program Manager has not been able to clearly communicate the justification for his budget requests and the rationale for the cost growth because NASA has lacked a single standardized accounting system and the program has not developed and maintained a baseline lifecycle cost estimate. Past efforts to control costs through budgetary constraints have failed to achieve their stated purpose and have probably exacerbated the cost growth.

Although the program office does not have a lifecycle cost estimate for the program, the CAST reviewed cost estimates of several elements of the program. These cost estimates vary from good to poor in terms of the quality of the approach, and are focused on the next few budget years.

Staffing levels for O&S reflect an extremely conservative risk-mitigation culture of Human Space Flight programs when compared to industry and DoD programs.

The budget for the ISS research program, having been transferred from the ISS budget line within Human Space Flight, appears to be disconnected from planned research content and more problematically from planned ISS capability under the NASA-OMB agreement.

An area not examined by CAST that has the potential for significant cost growth over the proposed OMB budget, is the effect of the NASA-OMB agreement eliminating further development of the planned seven-crew capability on International Partner Agreements. These agreements establish the cost-sharing arrangements of the International Partners on future operations and logistics costs in return for research capability associated with a seven-crew Station. A permanent three-crew Station will necessitate re-negotiation of these agreements, and NASA is likely to be forced to assume a greater share of these costs.

Without the establishment of a cost discipline as recommended by the CAST, the program can be expected to continue to struggle to control and understand future cost growth.

Appendix A – Cost Analyst Support Team Members

Mr. Steve Miller (Chairman), DoD Cost Analysis Improvement Group

Lt Col John Tomick, DoD Cost Analysis Improvement Group

Mr. George Flach, Naval Center for Space Technology

Mr. Michael Peters, Air Force Cost Analysis Agency

Mr. Jim Bui, MITRE

Mr. Kurt Held, RAND

Mr. Liam Sarsfield, RAND

Mr. Jeff Drezner, RAND

Mr. Rey Carpio, NASA Independent Program Assessment Office

Mr. Robert Shishko, NASA Jet Propulsion Laboratory

Appendix B - Projections of ISS Total Cost through Assembly Complete(*).

The chart and associated table provide the total costs of the ISS program through assembly complete as projected by fiscal year budgets. The final two bars represent the NASA budget requests to OMB for FY02-06. Each bar is segmented into the five major line items in the FY00 budget structure: Vehicle DDT&E, Russian Program Assurance, Crew Return Vehicle, Operations Capability, and Research. Each budget's associated assembly complete date is included as a label above each bar.

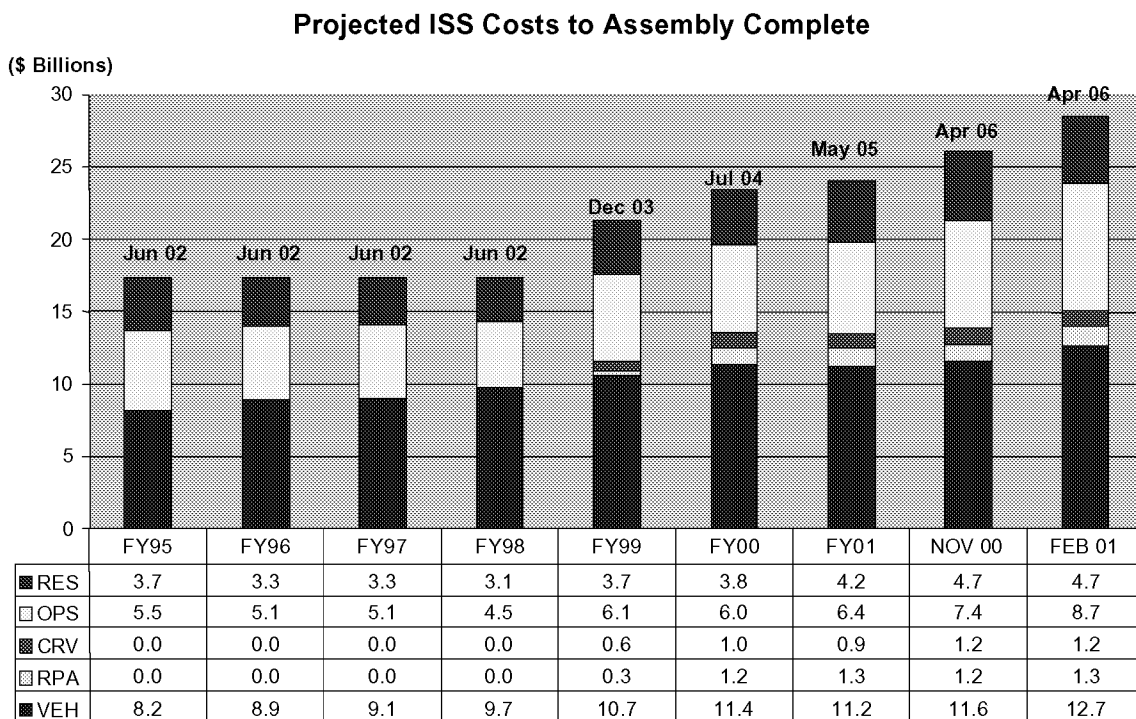


Figure B-1. Projected ISS Costs to Assembly Complete

* "Total Cost" includes the accumulated costs of the ISS budget line beginning with FY94. It does not include costs incurred by the original Space Station Freedom program prior to the 1993 redesign, in-house civilian personnel costs, principal investigator costs associated with the ISS research program, or Space Shuttle launch support costs to assemble and supply the Station.

Appendix C - Overview of MESSOC.

C.1 Introduction.

MESSOC (Model for Estimating Space Station Operations Costs) is a cost and resource-estimating tool for the mature operations phase of the International Space Station (ISS). First developed for Space Station Freedom, MESSOC 3.X versions were redesigned and updated for the International Space Station under the sponsorship of the NASA Independent Program Assessment Office (IPAO). The purpose of MESSOC is to inform ISS decisions through the lifecycle cost management process, to aid in the preparation of budgets, to support international operations cost-sharing analyses, and to identify long-term on-orbit resource envelopes.

MESSOC provides the analyst with the ability to test the effect of changes in ISS design, operations, and policies on both estimated operations costs and Station performance metrics. The metrics include crew time available to Station users, on-orbit availability of critical Station equipment, and user-dedicated payload mass to orbit. Operations cost estimates alone are not sufficient to address key design and operations issues. These estimates must be tied to useful measures of Station operations performance in order to establish the proper balance between cost and effectiveness.

The heart of MESSOC is a set of integrated algorithms and equations, linking operations costs with performance. Inputs to the algorithms come from two sources—those variables entered or edited by the analyst directly in dialog boxes and spreadsheets, and those data contained in MESSOC data tables. Variables entered in dialog boxes and spreadsheets create a Space Station scenario. In constructing a scenario, the analyst essentially tells the algorithms what the Station configuration is over time, what operations are being conducted aboard the Station over time, and what overall Space Station program and policy variables are in effect. The scenario spreadsheets provide a natural mechanism by which to capture Station evolution and growth.

From a Space Station scenario, the cost algorithms calculate costs in 20 functional categories (e.g., training operations). These costs, when summed, give total operations costs in a given year. The calculations are performed for each year of the Station's operational life, taking into account changes in its configuration, on-orbit and ground operations, as well as certain other intertemporal variables. Because of the nature of the algorithms, considerable detail is also available within the 20 cost categories and three operations performance categories for each year.

The 20 cost categories in MESSOC cover the costs of (a) planning and executing tasks associated with sustaining and operating the basic Station elements, (b) planning and executing tasks associated with training and sustaining Station crews, (c) providing the launch, communications, and data handling services to the Station and its users, and (d) helping users with Station integration, user logistics, and real-time user operations support. MESSOC does not cover such costs as the design and development of unique user payloads or experiments, or the development and operation of independent user operations facilities (UOF). MESSOC cost categories cover costs that go beyond direct Station responsibility. Other NASA organizations have responsibility for some costs estimated in MESSOC. Equally important, international partner costs are also calculated in

MESSOC and are reported under the same 20 functional cost categories. Because of the level of detail at which MESSOC algorithms work, these partner costs can be separated.

MESSOC software is written entirely in VBA, and is designed to run as an Excel file within Office '97 (or better). The user interface employs modern GUIs (Graphical User Interfaces) familiar to Excel users. Help topics and key assumptions (in the standard Microsoft help file format) can be displayed from the **Help** menu. The main quantitative data tables are kept “in the background” so that the novice analyst can maintain an underlying consistency across different scenarios, but these data tables can be accessed and changed for more complex model applications.

C.2 Cost Categories.

The cost categories in MESSOC were selected to cover a generic set of operations functions and activities, and therefore are meaningful across International Partners. In this way, identical functions or activities are costed using the same algorithms and equations. Table C-1 shows the 20 cost categories in MESSOC. To some, the absence of on-orbit functions from these categories may seem to be an oversight, but no money changes hands on-orbit; all resources are bought and paid for “on the ground.” On-orbit time utilization is extremely important for operations effectiveness, however, and this is emphasized by the extensive calculations made for on-orbit crew time.

Table C-1. MESSOC Cost Categories

1	<i>Space Station Control Center (SSCC)/Engineering Support Center (ESC) maintenance and support</i>
2	<i>Training operations</i>
3	<i>Flight design</i>
4	<i>Flight planning</i>
5	<i>Flight implementation</i>
6	<i>Sustaining engineering</i>
7	<i>Software Support Environment (SSE), TMIS, and information systems support</i>
8	<i>Other Integrated Logistic Support (ILS)</i>
9	<i>Intermediate/depot-level repair</i>
10	<i>Flight equipment spares</i>
11	<i>Element processing/reprocessing</i>
12	<i>Station consumables</i>
13	<i>Ground Support Equipment (GSE) maintenance and support</i>
14	<i>User integration operations</i>
15	<i>Flight crew pay and allowances</i>
16	<i>Integration management and institutional support</i>
17	<i>Program taxes and reserves</i>
18	<i>Data handling operations</i>
19	<i>NSTS/ELV launch services</i>
20	<i>Tracking and Data Relay Satellite System (TDRSS)/NISN services</i>

C.3 Model Architecture.

As mentioned earlier, the heart of MESSOC is the set of operations cost and performance algorithms. Inputs to these algorithms are supplied through a graphical user interface and Excel-like data tables. The user interface allows the analyst to construct a Space Station scenario by editing parameters and making choices within a set of programmatic, logistics, transportation, and crew factor dialog boxes, along with two spreadsheets, called the Configuration Profile and the Operations Profile. The Configuration Profile allows the analyst to describe the Station in terms of on-orbit hardware elements over the period of time for which cost estimates are desired. The Operations Profile allows the analyst to represent the overall structure of on-orbit and ground operations over the same period. MESSOC uses the Marshall Engineering Thermospheric (MET) Model, run separately, to compute average atmospheric densities for calculating drag forces on the Station during operations. A macro-view of the architecture is shown in Figure C-1.

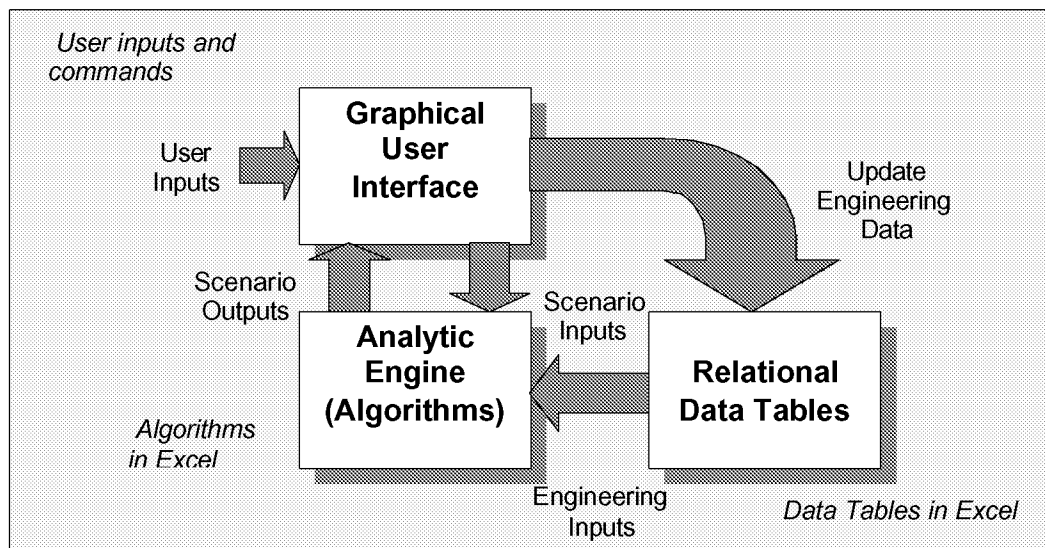


Figure C-1. Macro-view of MESSOC Architecture

C.4 Supporting Data Tables.

The Configuration Profile is supported by several logistics data tables that contain detailed information on each orbital replacement unit (ORU). These logistics data include on-orbit and ground maintenance characteristics such as Mean Time Between Failure (MTBF), how each failed ORU is to be treated, who will maintain it, how long each maintenance task (both corrective and preventive) will take, what parts might be used to effect repair, mass, and price. The primary source of logistics data for MESSOC is the MADS (Modeling and Analysis Data Set) assembled for the Space Station Program Office/Logistics and Maintenance.

The Configuration Profile is also supported by a data table containing, for each on-orbit hardware element, its physical parameters, such as overall element mass and frontal area, as well as data on transportation, processing, and sustaining engineering parameters. A separate data table relates (facility-class) orbital research facilities (ORF) to the on-orbit hardware elements in which they are located.

Several distinct data tables support the Operations Profile, too. Training data tables provide the link between the flight crew, ground personnel, and launch site personnel requirements and training operations costs. A facilities data table provides detailed information on each major ground facility and operations support center, and a launch vehicle data table provides detailed characteristics of those launch systems that might be used to support Station.

MESSOC data tables follow modern relational database management practices. The data in MESSOC are not intended as replacements for existing engineering, logistics, and training databases, but as copies of them. Consequently, to produce cost estimates that reflect the most current Space Station program, these data tables must be maintained in a timely fashion.

C.5 Algorithms and Equations.

MESSOC algorithms and equations are causal. Greater Station complexity, activity rates, and/or Station size gives rise to greater estimated operations costs in a systematic way. Further, to the extent that the many options could be anticipated, MESSOC was designed to handle a variety of policies.

To produce cost estimates with causal relationships to program decisions, four qualities were built into the model's algorithms and equations. First, wherever possible, operations costs are built up from the lowest level of data that were practical to obtain. Because the Station logistics databases and algorithms operate at the ORU level or lower, a change in design of a subsystem that affects the number or characteristics of its ORUs, for example, will result in a different estimate of operations costs. ORUs that are common across several flight hardware elements can be so recognized. This provides a very specific and natural way of treating the operations cost effects of commonality in the Station's design.

Second, algorithms and equations are linked to each other so that calculations made in one block of equations would be passed to another when needed. For example, an increase in the frequency of logistics resupply flights to the Station acts directly in the processing/reprocessing algorithm to increase those estimated costs, and acts indirectly to increase flight design costs and launch site training costs as well. As another example, MESSOC can be used to determine the effect on training costs of not only design changes that increase the need for extra-vehicular activity (EVA), but also of changing EVA suit design and operations policies regarding EVA safety. This is possible because of the linked nature of the cost drivers and the detail built into the training and logistics algorithms.

Third, as previously argued, operations cost estimates alone are not sufficient to address key design and operations issues. For example, a change in a subsystem design or operations policy might have very little effect on operations costs, but might significantly increase on-orbit maintenance time. Unless this was known, the wrong decision might be made. Consequently, MESSOC was

designed to calculate several measures of operations performance—net crew time available to users, subsystem or component availability, and net user payloads to orbit—at the same time it calculates costs, and to do so by using data passed from the cost algorithms. A conceptual view of how cost and operations performance blocks are related is shown in Figure C-2.

Last, the MESSOC software incorporates several logical checks to ensure the appropriate timing of costs, and to help the analyst avoid logical errors when constructing a Space Station scenario. For example, error checking tells the analyst when there are insufficient STS flights to support a proposed crew rotation policy, or when the number of crew persons exceeds the capacity of the habitability module(s). Additional checks are performed during algorithm execution to ensure that all data needed to compute an equation appear in the data tables.

The model's algorithms and equations calculate costs deterministically or as expected values in the case of the logistics outputs. Therefore, it is quite likely that actual operations costs will differ from the MESSOC estimate in any year since actual costs tend to be stochastic. It is possible, through the judicious manipulation of the MESSOC databases, to obtain a range of operations cost estimates, should the analyst desire to do so.

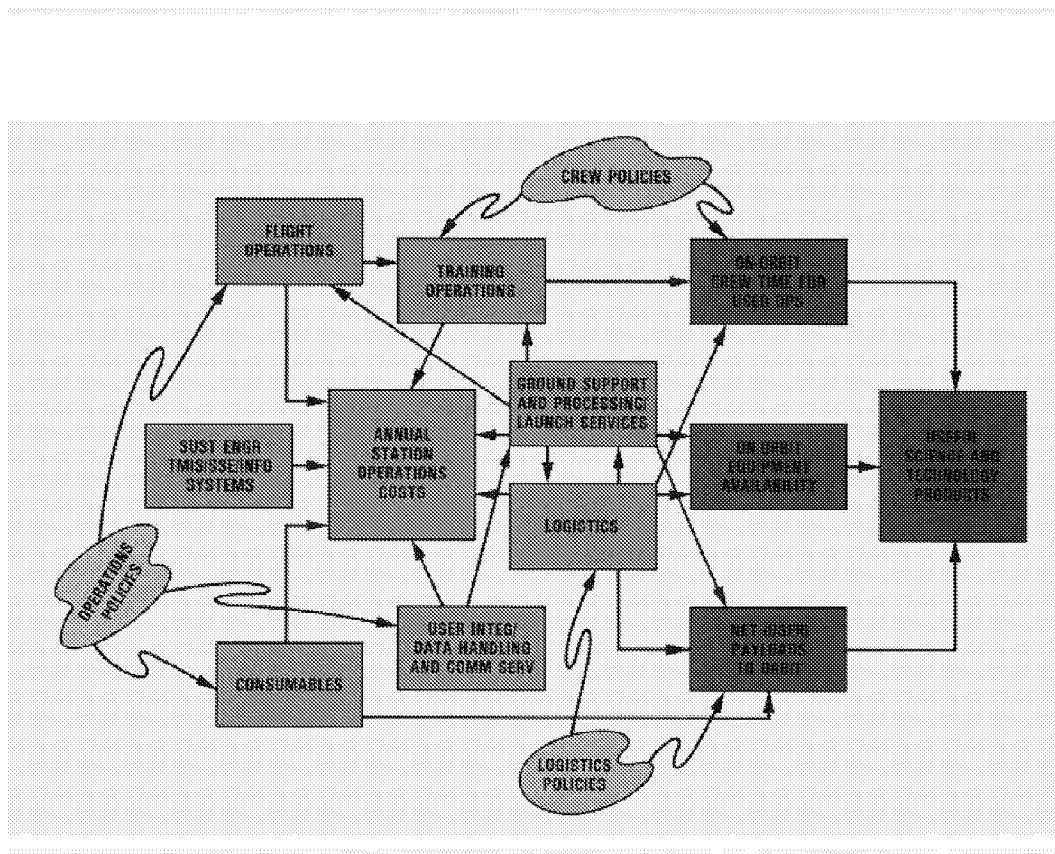


Figure C-2. Conceptual View of MESSOC

C.6. Algorithm Documentation

The algorithms and equations form a complex structure that will be completely understood by only a few analysts. Nevertheless, a substantial effort has made to document the algorithms and equations in mathematical (as opposed to source code) and narrative forms. Open algorithms and equations, it was felt, would make analysts more effective in the use of MESSOC. In MESSOC Version 3.X, this documentation is accessible on-line using a browser-type interface, rather than in hard copy.

C.7. Displayed Outputs

MESSOC computes and displays operations costs and operations performance outputs for each year of the scenario created by the analyst. From menu bar item **Outputs**, the analyst can access all results. The highest level outputs (both cost and operations performance) along with key Space Station scenario variables are found on the summary report. The summary report also displays discounted and undiscounted cost totals. The analyst can obtain detail for each of the 20 cost categories, and can get detailed breakdowns of how flight crews spend their on-orbit time, delivered consumables mass, recoverables mass and volume, and training loads. Any MESSOC input or output file can be displayed graphically using Excel's chart wizard.

Appendix D – Sample List of ISS Requirements and Program Documents

General ISS Program Documents

Concept of Operations and Utilization

Space Station Program Systems Specification 41000 (SSP 41000)

Station Program Implementation Plan (SPIP), Volumes 1-9

Assembly Sequence, Revision G (PICB)

Training Program Specific Documents

ISS Program Management Directive on ISS Crew and Flight Controller Training

ISS Crew Training Forecast

Space Station Training Facility (SSTF) Loading

Flight Controller Operations Handbook (SFOC FL-2318)

Flight Rules (NSTS 12820)

Flight Controller Certification Guides

APPENDIX E: FINANCIAL MANAGEMENT TEAM (FMT) INTERIM REPORT

Financial Management Review

ISS

October 23, 2001

Background

NASA Headquarters management, the Executive Office of the President, and the Congress have expressed great concern over the emergence of the revised ISS program funding estimates. Although there is general recognition that the ISS poses challenges, caused largely by the lack of previous experience with constructing and operating a space station, there is a substantial question as to why the program management did not recognize earlier and provide advance warning of the large funding increases. Was there a lack of sufficient expertise in the program control personnel of the Space Station that manifested itself in program management not receiving convincing analyses about the likely program costs? Was the information provided to the ISS program control group inadequate? Were the contractors providing reliable information on current program performance and resource consumption that would have warned the program control group that a “bow-wave” of scheduled work was being displaced by unscheduled work? Did NASA’s contract approach for the prime and non-prime activities inhibit reliable forecasts of future year funding requirements? Were civil service, institutional support, and contract costs appropriately factored in to the analyses?

The output of this effort is intended to provide NASA management with an understanding of the financial and program control tools needed to undertake difficult ventures such as the ISS. It will also support on-going NASA strategic resource planning by identifying shortfalls and needed remedial action to the program control workforce that management relies upon to provide reliable projections of funding needs.

Mission

The FMT mission is to develop an efficient and dynamic analytical, organizational and reporting framework to be used for the financial evaluation and management of the ISS program throughout its lifecycle.

Purpose

The FMT will provide an independent assessment and prioritized recommendations for improving the information available to NASA management on the resources requirements of Office of Spaceflight programs. With specific regard to the International Space Station, there is a pressing need to increase the confidence of the decisionmakers at

NASA Headquarters, OMB, and Congress in NASA budget estimates. ISS budget plans must be compliant with Presidential budget guidance and Congressional spending caps. Recommendations should also take into account the management information needs that result from reliance on the International Space Station partners to provide necessary capabilities and the close coupling of the ISS program with the Space Shuttle.

Executive Summary

The key findings were centered on the status and related strengths and weaknesses of the financial management component of the ISS program along with identifying specific programmatic and organizational issues impacting the overall financial analysis and planning capabilities of both HQ and the concerned centers.

The initial conclusions reached by the FMT are that the current weaknesses in financial reporting are a symptom, not a cause, of the problem; additionally, enhanced reporting capabilities (e.g. full IFMP operational deployment in '06) will not thoroughly solve the problem and, finally, the current financial function at both HQ and Center level is ill-defined and not capable of on-going and timely "forward" financial analysis and planning.

The initial recommendation is to reorganize the financial management structure of the Centers and redesign the distribution of financial authority and responsibility between HQ and JSC. This action would aim to give the JSC CFO function an enhanced ability to participate and challenge the financial assumptions presented by the program office for mid and long term resource planning. In addition, the adoption of an internal Full Cost Accounting system would bring additional transparency to the true cost of the program and more accurately quantify the contribution of NASA's technical resources.

Finally, during the design and implementation phases of the forthcoming Integrated Financial Management system (IFMP) the rapid identification and adoption of interim COTS financial analysis and reporting system capabilities would provide an "early warning" capability meeting some of the ISS program's internal and external financial reporting and forecasting requirements.

Financial Management Status

The Current Year Budgeting process and results appeared to both reliable and accurate but the exercise is both complex and lengthy due to the unique program structure of the ISS and its multi-center and international partner characteristics. In addition to the core budgeting functions, the task level financial accounting and cost tracking capabilities, at Center level are properly matched to short term resource identification and reporting requirements.

Major program-level financial forecasting and strategic planning functionality is weakened by diverse and often incompatible Center level accounting systems and uneven and non-standard cost reporting capabilities.

From a Cost Analysis standpoint, the FMT identified insufficient “forward” analysis and planning due to current division of financial authority and responsibility and lack of experienced financial resources. On the positive side, core capabilities of the existing financial function include reliable cost tracking, next-year Budgeting, Center-level Financial Accounting and reporting transparency capabilities managed by a dedicated and committed staff.

Finally, identified weaknesses include mid and long-term cost planning capabilities, financial performance analysis, cost management, downward reporting transparency, chronic short staffing in the financial analysis area both at Center and HQ level, poorly defined Controller and Finance functions and the ability to perform on-going and timely Independent assessment of Contractor cost estimates.

Cost Control and Analysis Issues

Three major issues were identified in relationship to NASA’s ability to identify, analyze and manage potential medium and long-term cost risks and issues:

- *Prime relationship /contract characteristics*

Although potentially positive from a task management standpoint, the relationship between NASA and its prime contractor might be closer than warranted on financial planning and budgeting matters. This is due in great part to the de-facto sole source, nearly cost plus nature of the contractual environment and the variety of skills and experience found in the ranks of the contractor personnel assigned to ISS.

In some isolated cases, the “A team” is still tasked on the ISS program, but also, in many cases, due to a variety of reasons, some of which are beyond the Prime’s control (attrition, relocation, promotion), contractor staff, on a regular basis, needs to be brought up the learning curve at the Program’s expense.

- *Limited analytical capabilities at Center/HQ levels*

In addition to a stretched finance and resource planning staff both at HQ and Center level (due to successive administrative staffing reduction plans over the past five years), NASA now has a serious lack of internal resources possessing long-term expertise in aerospace financial analysis including (where applicable) earned value analysis and dynamic financial risk assessment. This situation has weakened the internal planning and critical cost assessment abilities of the Center’s financial function.

- *Program cost shift from developmental to operational*

As the ISS program transitions from a mostly developmental to an operational phase, no reliable assessment of mid and long term sustaining engineering and operational costs (LOE estimating) has been so far performed internally and/or independently. (e.g. The ratio of civil servants to contractor appears to hold steady over time, is that a valid assumption moving forward?).

The FMT did not identify, with this programmatic evolution, the transition to a different set of performance-based financial metrics such as cost/schedule valuation and optimization matrices and the modeling of Program-wide distributed cost impact analysis of discrete element slippage.

Programmatic and Organizational Issues

As part of the FMT effort, we tested, through interviews at Center level, whether the current OMB budget guidelines have not only been adopted but used in long-term financial planning.

The general result of those inquiries was identifying a prevailing attitude that the program cannot be executed within the current budget boundaries and that the near-term “shortfall” will eventually be resolved through additional funding. As a consequence of those subjective views, the overall scope and direction of the Program is still unclear among the various affected “constituencies” within and outside NASA. This is reflected in continuous work being performed on research elements dependent on a seven person crew, and the unduly slow termination of contracts also affected by the “core-complete” set of developmental and operational objectives.

A secondary order derivative of this lack of front-end scope and definition, is the inability, for the ISS Program, to test the accuracy and validity of the contractor’s alternative staffing plans. On a more positive note, the Program just initiated a control improvement road map which will greatly help the identification and monitoring of potential problem areas before they reach a critical status.

Finally, under the current organizational structure, the financial management function is centered upon tracking and documenting what “took place” rather than what “could and should take place” from an analytical cost planning standpoint. In summary, Finance is not viewed as intrinsic to program management decision process.

Initial Recommendations

We recommend a thorough reorganization of the ISS cost control and analysis function in respect to the delegation of financial authority and responsibility among Program, Center and HQ:

- More specifically, we recommend increasing the capability of the Center's financial forecasting, budgeting and performance-analysis functions by identifying experienced Civil Service staff and assigning them to the Program at Center level.
- In addition, we also recommend the adoption of a Full Cost Accounting approach to civil service technical staff (not "free" resources) for internal analysis and trend impact forecasting purpose.
- We also suggest an earlier involvement of the HQ CFO staff in "testing and validating" Center financial plans upstream of the formal budgeting process, this option would also require the Center CFO to give final approval on ISS Program's financial forecasts and plans.
- Finally, a key decision has to be taken at HQ management level to develop an organizational structure which streamlines and matches financial authority, responsibility and flow of information among Program, Centers and HQ.

Exhibit 1:

FMT Tasks

1. Analyze the circumstances attendant to the failure of the ISS program office to provide reliable forecasts of future funding requirements.
2. Identify priority areas for attention to redress financial analysis weaknesses
3. As appropriate, recommend metrics for use by the Chief Financial Officers of the Centers and NASA Headquarters.
4. Define a set of alternative scenarios NASA could improve its organizational approach to complex programs, including fiduciary responsibilities, improved lines of responsibility, and transparency for monitoring management execution.
5. Identify critical capabilities in program control that must be retained by or rebuilt within NASA and others where reliance on sources outside of NASA would be effective. Identify opportunities for outsourcing aspects of program control to fully leverage outside expertise

APPENDIX F: NOMENCLATURE

AA	Associate Administrator
BoE	Bases of Estimates
CAM	Centrifuge Accommodation Module
CARD	Cost Analysis Requirements Document
CAST	Cost Analysis Support Team
CRV	Crew Return Vehicle
CSA	Canadian Space Agency
CY	Calendar Year
DOD	Department of Defense
EAC	Estimate at Completion
ECLSS	Environmental Control and Life Support Systems
ESA	European Space Agency
EVA	Extra Vehicular Activity
FMT	Financial Management Team
FY	Fiscal Year
GRC	Glenn Research Center, Cleveland, OH
HSF	Human Space Flight
IMCE	International Space Station Management and Cost Evaluation
IP	International Partners
ISS	International Space Station
JSC	Johnson Space Flight Center, Houston, TX
KSC	Kennedy Space Center, FL
MOU	Memorandum of Understanding
MSFC	Marshall Space Flight Center, Huntsville, AL
NAC	NASA Advisory Council
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
OBPR	Office of Biological and Physical Research, NASA Headquarters, Washington, DC
OMB	Office of Management and Budget, Washington, DC
OSF	Office of Space Flight, NASA Headquarters, Washington, DC
POP	Program Operating Plan
Program baseline	Test program schedule and milestones
Program Manager	Responsible for managing all aspects of program
Program Team	Government and industry individuals assigned to test program
R&D	research and development
RSA	Russian Space Agency
SRR	Strategic Resources Review